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ABSTRACT

A comprehensive national database on key quantitative and qualitative aspects of scientific and engineering research facilities at universities and colleges is presented. This study was conducted in response to a Congressional request for systematic information on the status of academic research facilities. The National Science Foundation (NSF) was directed to "design, establish, and maintain a data collection and analysis capability for the purpose of identifying and assessing the research facilities needs of universities and colleges." Seven chapters look at the following: (1) introduction (background, presentation of the data and organization of the report); (2) current amount of research space; (3) new construction and repair/renovation of research facilities; (4) sources of funds for research facilities projects; (5) condition and adequacy of research facilities; (6) research facilities at historically black colleges and universities; and (7) comparison of 1986 and 1988 research facilities surveys. Some of the findings are: major sources of funds for research facilities include state/local governments, private funds, institutional funds, and tax-exempt bonds; actual and planned repair/renovation costs for the period 1986-1989 total about $1.6 billion; and institutions reported actual and planned construction projects totalling about $5.5 billion. Five appendices are as follows: technical notes; list of sampled institutions; facilities request and approval process; survey questionnaire; and detailed statistical tables. The report contains 30 tables, 4 charts, and 18 figures. (SM)

HIGHLIGHTS

- There are an estimated 114 million net assignable square feet (NASF) of research space available at the nation's research-performing universities and colleges. Nearly all of the space is located in doctorate-granting institutions. The top 50 research and development (R&D) institutions account for 61 percent of all R&D expenditures and 50 percent of the research NASF.

- Over 80 percent of the research space, and a similar proportion of R&D expenditures, are concentrated in five science and engineering (S/E) fields: the biological, medical, agricultural, and physical sciences, and engineering.

- Institutions reported actual and planned construction projects totalling about $5.5 billion. About $2.1 billion was reported for projects initiated in 1986 and 1987; institutions plan a substantial increase to about $3.4 billion in 1988 and 1989.

- Construction projects covered in this report involve a total of 22 million NASF of research space -- about 10 million in 1986 and 1987, and 12 million in 1988 and 1989, some of which will replace obsolete or unsuitable space.

- Based on the costs of construction at those institutions which reported inadequate amounts of research space and reported construction of research facilities, it is estimated that institutions are deferring about $2.50 in needed construction for every $1.00 of construction that is planned.

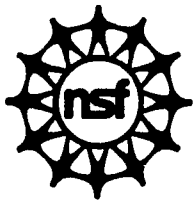
- Actual and planned repair/renovation costs for the four-year period 1986-89 total about $1.6 billion. The 1986 and 1987 level of $863 million is expected to decline to $777 million in 1988 and 1989.

- The amount of space to be repaired/renovated in 1988 and 1989 (9 percent of existing space) represents only a portion of the space needing repair/renovation (R&R). Based on the costs of reported R&R projects, it is estimated that about $3.60 in needed R&R is being deferred for every $1.00 in R&R that is planned.

- Major sources of funds for research facilities include State/local governments, private funds, institutional funds, and tax-exempt bonds. Public and private institutions utilize different funding mixes from the various sources. The Federal Government provides a comparatively small share for both public and private institutions (6 and 7 percent, respectively).

- The total institutional debt incurred from projects covered in this report will be about $1.4 billion, if all projects are completed and funded as anticipated.

SCIENTIFIC AND ENGINEERING RESEARCH FACILITIES AT UNIVERSITIES AND COLLEGES: 1988



National Science Foundation

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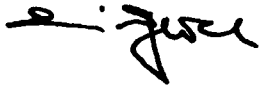
FOREWORD

Universities and colleges have traditionally provided the intellectual resources and new knowledge required to maintain and strengthen our nation's economic competitiveness and to train future generations of scientists and engineers. The facilities--bricks and mortar and associated infrastructure systems--that house the research enterprise at our academic institutions must be present in sufficient amounts and must be of suitable quality to allow science and engineering research and education at the highest levels of excellence.

Acting out of concern raised by the academic community, Congress directed the Foundation to establish a systematic data collection and analysis capability to assess the status and condition of academic research facilities and to report these findings to Congress. This report, the second in a biennial series, provides a comprehensive national data base on key quantitative and qualitative aspects of these facilities. Future surveys in this series will allow analysis of changes in the availability, cost, and condition of research facilities.



Erich Bloch
Director
National Science Foundation

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The 1988 Survey of Scientific and Engineering Research Facilities was conducted by Westat, Inc. under the sponsorship and direction of the Division of Science Resources Studies of the National Science Foundation (NSF) and the Office of Policy Analysis and Legislative Affairs of the National Institutes of Health (NIH). The following agency personnel guided the development of the study and provided technical oversight during the survey:

- Judith Coakley, Science Resources Analyst, Universities and Colleges Study Group (UCSG), NSF
- James Hoehn, Study Director, UCSG, NSF
- Charles Dickens, Head, Surveys and Analysis Section, NSF
- William Stewart, Director, Division of Science Resources Studies, NSF
- Ronald Geller, Director, Office of Policy Analysis and Legislative Affairs, NIH

Contractor staff who played significant roles in the preparation of this report were:

- Mary Collins, Project Director
- Kenneth Burgdorf, Technical Advisor
- Bradford Chaney, Analyst

An expert Advisory Panel contributed to the survey design, the analysis plan, and the review of this report:

- Dennis Barnes, Associate Vice President for Governmental Relations, University of Virginia
- Harvey Kaiser, Senior Vice President, Facilities Administration, Syracuse University
- Julie Norris, Assistant Vice President and Director of Sponsored Programs, University of Houston
- Kenneth Shine, Dean of the Medical School, University of California-Los Angeles
- Allen Sinisgalli, Director of Research and Project Administration, Princeton University

In addition, several higher education associations and university representatives advised NSF on the development of the survey in two workshops. The contributing associations included:

- The American Association of State Colleges and Universities
- The American Council on Education
- The American Society for Engineering Education
- The Association of American Medical Colleges
- The Association of American Universities
- The Council of Graduate Schools in the United States
- The Council on Governmental Relations
- The National Association of Independent Colleges and Universities
- The National Association of State Universities and Land Grant Colleges
- The National Council of University Research Administrators

Finally, we acknowledge the indispensable contribution of the many officials and staff members at the sampled institutions who undertook the completion of the survey questionnaires.

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EXECUTIVE SUMMARY

This study was conducted in response to a Congressional request for systematic information on the status of academic research facilities. The 1986 National Science Foundation (NSF) Authorization Act (P.L. 99-159, section 108) directed NSF:

> ...to design, establish, and maintain a data collection and analysis capability...for the purpose of identifying and assessing the research facilities needs of universities and colleges.... The Foundation, in conjunction with other appropriate Federal agencies, shall conduct the necessary surveys every 2 years and report the results to the Congress.

This report is the second in this biennial series, due to Congress in September, 1988. It is based on NSF's 1988 Survey of Scientific and Engineering Research Facilities at Colleges and Universities.

Current Amount of Research Space

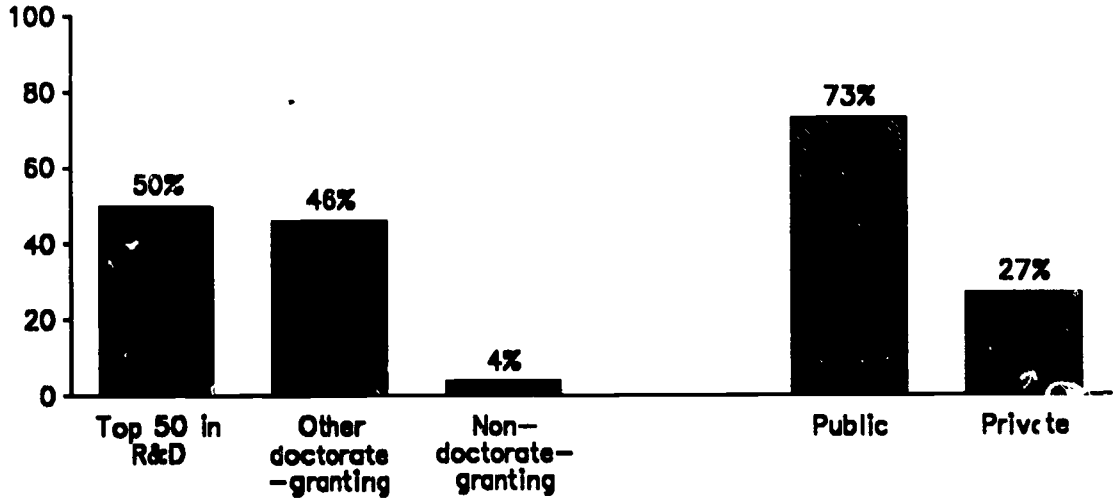
- There are an estimated 114 million net assignable square feet (NASF) of research space available at the nation's research-performing institutions. Nearly all of the space is located in doctorate-granting institutions. The top 50 research and development (R&D) institutions account for 61 percent of all R&D expenditures and 50 percent of the research NASF.

- Over 80 percent of the research space and a similar proportion of R&D expenditures are concentrated in five science and engineering (S/E) fields: the biological, medical, agricultural, and physical sciences, and engineering.

American universities and colleges contained an estimated 114 million square feet[1] of research space in S/E disciplines in 1988. Most of this research space was located in institutions that award S/E doctorates (96 percent). These institutions also accounted for nearly 99 percent of total academic R&D expenditures in fiscal year (FY) 1986. Nearly three-fourths (73 percent) of all academic research space was in public-sector institutions (Chart 1), somewhat higher than these institutions' 65 percent share of total R&D spending.

[1] All estimates of research space are based on net assignable square feet (NASF) assigned to organized research. See Appendix pages A-7 and D-4 for definitions.

Chart 1
Percent of total science/engineering research space, by institutional type and control: 1988



Reference: Table 1
Source: National Science Foundation, SRS

The top 50 institutions[2] in R&D expenditures -- all of which are doctorate-granting -- contain one-half (50 percent) of all academic research space and have a mean of 1.1 million square feet of research space per institution. Other doctorate-granting institutions, which contain most of the remaining research space (46 percent overall), average 217,000 square feet per institution. The 232 non-doctorate-granting institutions that report $50,000 or more in separately-budgeted annual R&D expenditures contain 4 percent of all academic research space, or an average of 20,000 square feet per institution.

Over 80 percent of the current academic research space is concentrated in five S/E disciplines: the biological (21 percent), medical (17 percent), agricultural (16 percent), and physical (14 percent) sciences, and engineering (14 percent). These five disciplines also account for approximately the same proportions of academic R&D expenditures.

Adequacy of the Current Amount of Research Space

In most disciplines, over one-half of all institutions described their current space as either **adequate** ("sufficient to support all the needs of your research") or as **generally adequate** ("sufficient to support most research needs...but may have some limitations"). By discipline, ratings of **generally adequate** or better ranged from a low of 48 percent of institutions with programs in engineering to a high of 74 percent of those with programs in mathematics.

Recent and Planned Facilities Construction Activity

- Institutions reported actual and planned construction projects totalling about $5.5 billion. About $2.1 billion was reported for projects initiated in 1986 and 1987; institutions plan a substantial increase to about $3.4 billion in 1988 and 1989.

- Construction projects covered in this report involve a total of 22 million NASF of research space -- about 10 million in 1986 and 1987, and about 12 million in 1988 and 1989, some of which will replace obsolete or unsuitable research space.

About three-fifths (59 percent) of all academic institutions plan at least one major facilities construction project involving research-related costs of $100,000 or more at some time during the 4-year period 1986-89.[3] This includes 47 of the top 50 R&D performers (94 percent). Collectively, these projects are expected to produce a total of 21.8 million square feet of new research space, the equivalent of 19 percent of existing research space.[4] The anticipated total cost of the research-related components of these projects is $5.5 billion; $2.1 billion in 1986 and 1987, and $3.4 billion planned for 1988 and 1989.

Within the 1986-89 period, anticipated construction costs increased sharply -- from $0.90 billion for projects started in 1986 to an annual average of $1.70 billion for projects planned to begin in 1988 or 1989 -- a rate of increase of about 30 percent per year. This increase in total construction cost is attributable to two factors:

- There was a steady growth of 10 percent per year over this period in the amount of research space under construction, from 4.7 million square feet for projects begun in 1986 to an annual average of 5.9 million square feet for projects with planned groundbreaking in 1988 or 1989; and

- There was an even larger increase of 20 percent per year in the unit cost of the research space being constructed, which grew from $192 per square foot in 1986 to an annual average of $288 per square foot for 1988 and 1989 combined. This suggests a marked increase in **technical and regulatory** requirements for academic research space.

[2] The top 50 R&D institutions were selected as an analytical grouping because they represent significant proportions of R&D expenditures (61 percent) and space (50 percent), and are the only group which is comparable between the 1986 and 1988 NSF surveys of academic research facilities. The reader should bear in mind that many institutions below the top 50 also have significant amounts of R&D expenditures and research space.

[3] All data on construction and repair/renovation projects are based on the institutions' fiscal years in which the projects were, or will be, initiated. For simplicity, references to the periods in which construction or repair/renovation begins omit the notation "FY"; it is understood that all such dates refer to the institutions' fiscal years.

[4] Construction-generated additions to existing research space do not necessarily constitute a net expansion in the total amount of available research space. In some cases, there are offsetting losses -- as obsolete facilities are demolished or converted to nonresearch uses.

These findings are consistent with reports from institutions indicating that new construction is driven at least as much by needs to upgrade the quality of their research facilities to meet emerging safety and other requirements as it is by needs to expand their total amount of research space. Among the factors often cited as contributing to the markedly increased costs of facilities construction were increasing standards for animal facilities, for toxic waste disposal, for biohazard control, and for data communication capabilities.

Relationship Between Need for Additional Research Space and Plans for Construction

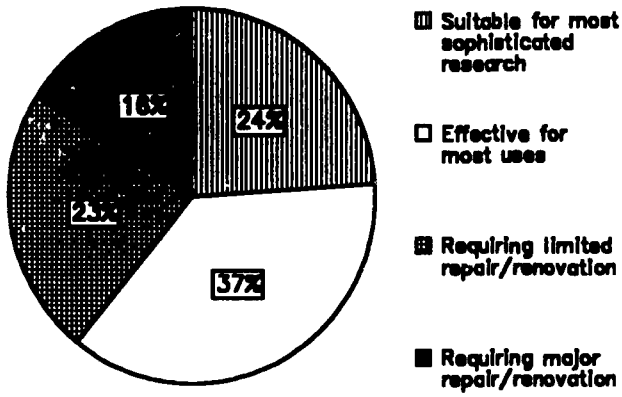
- Based on the costs of construction at those institutions which reported inadequate amounts of research space and reported construction of research facilities, it is estimated that institutions are deferring about $2.50 of needed construction for every $1.00 of construction that is planned.

Over two-thirds (69 percent) of the $3.4 billion in planned facilities construction in 1988 and 1989 is targeted for disciplines (within institutions) where the current amount of research space is reported to be inadequate. If all institutions that reported insufficient space in a discipline were planning to build additional space, at the same cost as that reported by institutions which do plan construction in the discipline in 1988 or 1989, the total construction cost would be $8.1 billion, about 3½ times larger than the amount these institutions actually plan to spend. This implies that, for every $1.00 of planned construction at institutions that need more research space, there is about $2.50 in deferred (i.e., needed, but not planned) construction. The disciplines with the lowest rates of deferred construction -- those with the smallest disparity between reported need for additional research space and reported plans to construct additional research space -- are the agricultural ($0.77 to $1.00), medical ($1.44 to $1.00), and biological ($2.01 to $1.00) sciences.

Condition of Current Research Space

About one-fourth (24 percent) of all space currently used for organized research in academic settings is reported to be "suitable for use in the most highly developed and scientifically sophisticated research in its field," and an additional 37 percent is described as "effective for most purposes..." (Chart 2). The remaining 39 percent is judged to be in need of limited (23 percent) or major (16 percent) repair/renovation to be used effectively. A general similarity was noted among fields for condition ratings.

Chart 2
The condition of science/engineering research space at universities and colleges: 1988



Reference: Appendix table 5–1
Source: National Science Foundation, SRS

Recent and Planned Facilities Repair/Renovation

- Actual and planned repair/renovation costs for the period 1986-89 total about $1.6 billion. The 1986 and 1987 level of $863 million is expected to decline to $777 million in 1988 and 1989.

- The amount of space to be repaired/renovated in 1988 and 1989 (9 percent of existing space) represents only a portion of the space needing repair/renovation (R&R). Based on the costs of reported R&R projects, it is estimated that about $3.60 in needed R&R is being deferred for every $1.00 in R&R which is planned.

In 1986 and 1987, academic institutions initiated major repair/renovation projects (projects with $100,000 or more in costs relating to R&D space) affecting 12 percent, or 13.7 million square feet, of all academic research space. For 1988 and 1989, institutions plan repair/renovation projects affecting an additional 9 percent (9.7 million square feet) of existing research space. Reported total costs of these projects declined somewhat, from $863 million in 1986-87 to an anticipated $777 million in 1988-89. In some cases, the decline from 1986-87 to 1988-89 in expected repair/renovation activity indicates a planned shift to greater emphasis on new construction. In other cases, it reflects

an underestimation of the extent to which future repair/renovation projects may be needed in response to changes in technical or regulatory requirements.

Over the 4-year period 1986-89, planned expenditures for facility repair/renovation total $1.6 billion, or about one-fourth (23 percent) of the $7.1 billion in total planned expenditures for both construction and repair/renovation. This pattern is generally stable across disciplines (Chart 3). Exceptions are computer science and agricultural sciences, in which more of the facilities-related expenditures (85 percent and 90 percent, respectively) involve construction of new facilities rather than repair/renovation of existing ones.

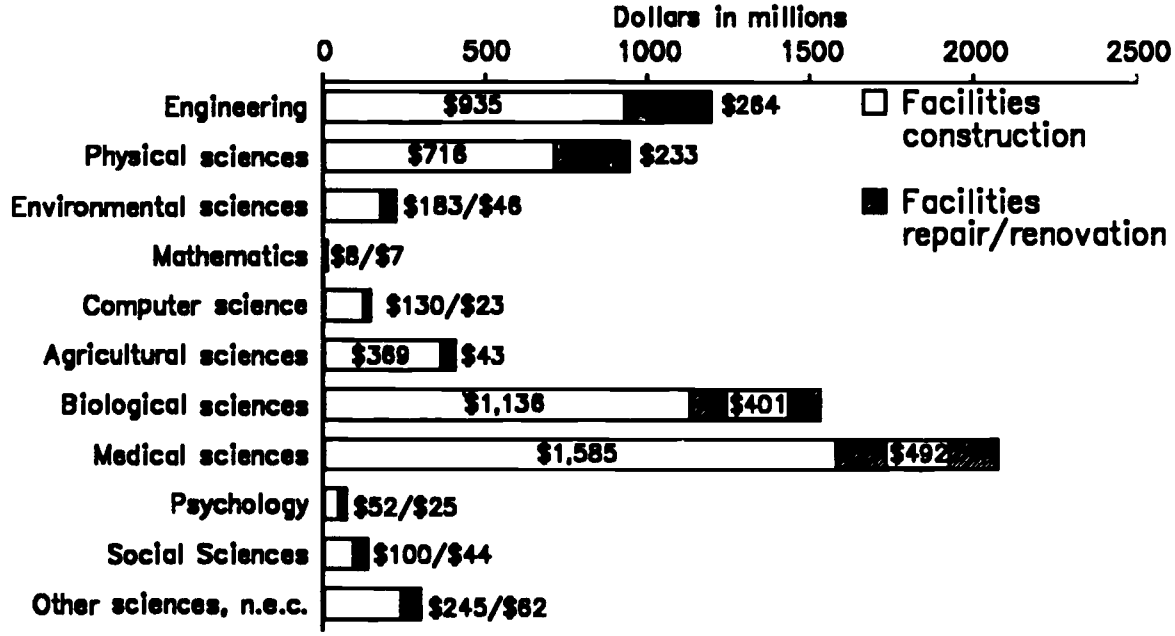
Deferred Repair/Renovation

One of the most common themes mentioned by academic officials in the open-ended survey responses concerned the backlog of necessary repairs and renovations, often of older facilities. Institutions indicated that the continued deferral of repair and renovation projects compromises the quality of the research space. The fact that the total costs and square footage involved in repair/renovation are declining over the 4-year period covered by this survey suggests a continuation of this deferral pattern.

In particular, there is a substantial disparity between the amount of research space institutions report to be in need of repair/renovation in 1988 (39 percent of all existing research space) and the amount they actually plan to repair or renovate in 1988 or 1989 (9 percent). If all research space needing repair/renovation were to receive it, at the same cost per square foot as was found at institutions actually planning such projects, the cost would total $3.6 billion, roughly 4½ times the amount institutions plan to spend. This means that, for every $1.00 institutions plan to spend for facilities repair/renovation in 1988-89, there is an additional $3.60 of repair/renovation that is needed but is being deferred to some future time.

As was found earlier for deferred construction, the disciplines with the lowest rates of deferred repair/renovation (i.e., the ones whose planned spending comes closest to meeting the estimated need in the discipline) are the medical ($2.10 to $1.00) and biological ($2.40 to $1.00) sciences. These are also the two disciplines with the highest absolute levels of recent and planned spending for both construction and repair/renovation of research facilities (Chart 3).

Chart 3
Anticipated total spending for construction and repair/renovation of academic research facilities, by discipline: 1986–89



Reference: Appendix tables 3–4 and 3–8
Source: National Science Foundation, SRS

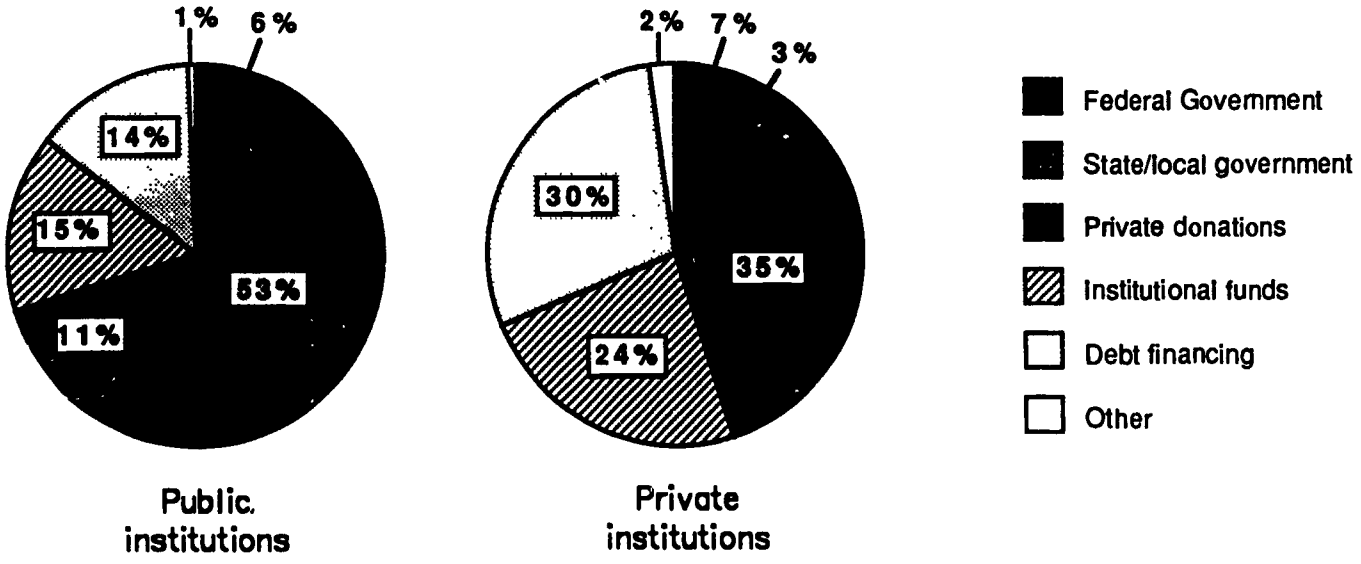
Sources of Funds[5] for Facilities Construction and Repair/Renovation.

- Major sources of funds for research facilities include State/local governments, private funds, institutional funds, and tax-exempt bonds. Public and private institutions utilize different funding mixes from the various sources. The Federal Government provides a comparatively small share for both public and private institutions (6 percent and 7 percent, respectively).

- The total institutional debt incurred from projects reported in this survey will be about $1.4 billion, if all projects are completed and funded as anticipated.

Public (i.e., State-operated) and private institutions report substantially different patterns of funding support for construction and repair/renovation of research facilities. Over the 4-year period from 1986 to 1989, State and local government sources account for over one-half (53 percent) of all planned facilities-related spending at public institutions, but for only a small fraction (3 percent) of the planned spending at private institutions (Chart 4). By contrast, private institutions rely more heavily than public institutions on funding support from private donations (35 percent vs. 11 percent) and on use of tax-exempt bonds or other forms of debt financing (30 percent vs. 14 percent). Federal sources account for comparatively small fractions of the facilities funding support of both public and private institutions (6 percent and 7 percent, respectively).

Chart 4
Sources of funds for construction and repair/renovation of academic research facilities: 1986–89



Note: Percents may not sum to 100 because of rounding.
Reference: Appendix tables 4–2, 4–4, 4–6, and 4–8
Source: National Science Foundation, SRS

[5]This report includes data on the direct costs of construction and repair/renovation and the sources of funds for these direct costs. No attempt was made to quantify future indirect cost pressures resulting from current or planned projects.

Among private institutions, debt financing and private contributions both account for larger shares of the funding for construction projects than they do for repair/renovation projects, and conversely, internal college or university funds (excluding debt financing) account for a considerably larger share of the costs of repair/renovation projects (43 percent) than of construction projects (16 percent). Similar differences in the funding of construction vs. repair/renovation projects are seen at public institutions, although the effects are attenuated by the overriding influence for both types of projects of funding from State and local governments (53 percent of the funding for both construction and repair/renovation).

The total institutional debt incurred from projects reported in this survey is approximately $1.4 billion, if all projects are completed and funded as anticipated. About $812 million of this debt has been, or will be, incurred at private institutions; about $953 has been, or will be, incurred by the top 50 research universities.

Private institutions reported an anticipated 60-percent increase in the use of tax exempt bonds for capital projects in 1988 and 1989 when compared to 1986 and 1987. For private institutions only, recent legislation has placed a $150 million limit on outstanding tax exempt bonds. This $150 million cap may have an impact on future funding for facilities projects, particularly for institutions in the top 50. Twenty percent of all private doctorate-granting universities have reached the limit, and an additional 8 percent expect to do so in the next 2 years. Among the 19 private institutions in the top 50, however, 11 reported that they have already reached the cap, while another 3 anticipate doing so over the next 2 years.

Research Facilities at Historically Black Colleges and Universities

Of all S/E space at historically black colleges and universities (HBCU's), 19 percent or 1 million NASF is used for research. This represents 1 percent of the total NASF for all institutions, similar to the HBCU share of total academic R&D expenditures.

HBCU's obtained more than 80 percent of their funding for new construction and repair/renovation projects from government sources. Federal (45 percent) and State/local government (36 percent) sources combined accounted for 81 percent of construction in 1986 and 1987; comparable shares for repair/renovation activities were 61 percent and 35 percent. For planned 1988 and 1989 activities, total project costs are less than for the preceding two years. State and local funding is expected to exceed Federal funding, and virtually no funds are reported from institutional sources, tax-exempt bonds, or other debt.

Methodology

Concurrent with the conduct of the first NSF facilities survey in 1986, an expanded full-scale baseline study was designed, to be used for the second iteration of the facilities study.

NSF developed the 1988 survey instrument in cooperation with several higher education associations, university representatives, and an expert advisory panel. The scope of the 1988 facilities survey was expanded to include information on predominantly undergraduate institutions and historically black colleges and universities as well as information on a broader range of doctorate-granting institutions. In addition, quantitative as well as qualitative data were collected for individual science and engineering fields, which provided a more detailed picture of the amount and condition of available research space, recent and planned repair/renovation and construction activities, and sources of funds for these capital projects for the years 1986 through 1989.

After the initial survey design phase, the questionnaire was pretested at a diverse group of 22 universities and colleges throughout the Nation. Site visits were made to discuss the survey instrument and procedures as well as the accessibility of requested data from institutional records. The full-scale survey was conducted during the fall and winter of 1987-88.

The data in this report were obtained from a stratified probability sample of 244 universities and colleges in a universe of 524 institutions, selected on the basis of R&D expenditures in science and engineering in FY 1983. All of the schools ranked in the top 50 in terms of R&D expenditures, and 98 of the top 100, were sampled. All historically black colleges and universities with R&D expenditures were included. The sample represented more than 75 percent of total academic R&D expenditures and at least 70 percent of spending in each S/E discipline.

Findings from the 1988 study are statistically weighted to provide national estimates for all schools that perform R&D activities. While medical schools were surveyed separately, they reported the same information as all other schools. The response rate was 90 percent for all universities and colleges, and 89 percent for medical schools.

1. INTRODUCTION

Background

In recent years, the higher education community has become increasingly concerned about the status of academic science and engineering research facilities. Various reports have indicated that there is a wide range in the adequacy of existing college and university research facilities. Some are excellent; others are inadequate to support the institutions' research efforts as a result of the aging of buildings, the deferral of necessary maintenance, and the need for sophisticated environments to support new technologies.

Some institutions have also reported that they are unable to secure funding for projects to repair, renovate, and construct research facilities because of economic constraints on State appropriations and increasing plant debt. With the implementation of recent tax reform legislation, additional concerns have been raised regarding the financing of facilities because of the limitation on tax-exempt bonds that private institutions may have outstanding and the decreasing tax advantages of private gifts.[1]

Acting out of these concerns, Congress, in the 1986 NSF Authorization Act (P.L. 99-159, Section 108), instructed the National Science Foundation:

> ...to design, establish, and maintain a data collection and analysis capability in the Foundation for the purpose of identifying and assessing the research facilities needs of universities.... The Foundation, in conjunction with other appropriate Federal agencies, shall conduct the necessary surveys every 2 years and report the results to the Congress.

This report presents the findings of the 1988 Survey of Scientific and Engineering Research Facilities. This is the first full-scale survey to be conducted on this topic. Future data collections in this biennial series will enable analysts to detect changes in the availability and cost of research facilities, and will indicate improvement in or worsening of their condition.

The 1986 NSF Academic Research Facilities Survey

The first NSF report to Congress in response to this mandate was due September 1, 1986, less than one year after the legislation was passed. To meet the schedule, the Foundation used an existing "quick-response"[2] survey mechanism, the Higher Education Surveys (HES), to collect data during the spring of 1986. The surveys were limited to institutions classified as doctorate-granting in the Department of Education's Higher Education General Information Survey (HEGIS), the universe for the HES panel.

A mail questionnaire was used to collect quantitative data on science and engineering research facilities. Items included the amount of research space available; costs of repair, renovation, and new construction in progress in academic year 1985-86 and planned for academic years 1986-87 through 1990-91; the sources of funds for these projects; and the age of R&D facilities. Because of the short turnaround time needed to meet the Congressional due date, the survey did not collect square footage or project cost data by individual science and engineering discipline.

A companion telephone survey was used to collect qualitative information regarding the status and adequacy of research facilities in science and engineering disciplines from research administrators and deans at a subset of the same schools represented in the mail survey. The telephone questionnaire included items on the condition of research facilities, the adequacy of the amount of research space available, the effects of facilities needs on the institutions' research programs, and difficulties that the institutions faced in addressing their facilities needs.

The 1988 NSF Academic Research Facilities Survey

While the 1986 NSF "quick-response" surveys were being conducted, the Foundation began the development of an expanded survey to be conducted in 1988, and every two years thereafter. The National Institutes of Health (NIH) joined NSF in sponsoring the expanded survey. Development of the survey benefited from the assistance of higher education associations, university representatives, and an expert advisory panel representing five research universities. A group of higher education associations sponsored a workshop in the spring of 1987 for the purpose of advising NSF and NIH on the content of the survey questionnaire. During the summer of 1987, NSF, NIH, and contractor staff conducted site visits at 22 colleges and

[1] Bricks and Mortar: A Summary and Analysis of Proposals to Meet Facilities Needs on College Campuses. Congressional Research Service, 1987.

[2] A quick-response survey system is one that utilizes brief questionnaires (usually only two or three pages) to collect limited amounts of data. Generally, these surveys have brief time frames in order to respond to issue-related data requests.

universities. During these site visits, which contributed greatly to the development of the survey, data collection issues, definitions, and questionnaire items were discussed in-depth with research administrators, facilities and budget officers, science and engineering deans, and principal investigators. The findings of the pretest site visits were presented in another association-sponsored workshop in the early fall. There was general agreement with the overall design of the survey instruments that resulted from this cooperative effort.

The 1988 survey builds upon, and goes considerably beyond, the 1986 study. As a result, the two survey efforts differ in significant ways. The majority of the differences are related to the survey samples and to the level of detail requested in the questionnaires and are presented in Exhibit A-1 in Appendix A: Technical Notes. The following paragraphs briefly describe these differences.

The sample for the 1988 survey included a broader range of institutions than the 1986 survey. The 1988 survey's universe of approximately 525 institutions includes all those that award doctoral or master's degrees in the sciences and engineering, all other institutions that have separately budgeted research expenditures of $50,000 or more, and all historically black colleges and universities (HBCU's) with any research expenditures. A sample of 244 institutions was selected with probability proportional to size, as measured by total science and engineering R&D expenditures.[3] The sample included all of the top 50 research universities, and 98 of the top 100, based on total R&D expenditures. In order to provide reliable estimates for research facilities at HBCU's, all 29 of those with separately budgeted research expenditures were included in the sample. Data were collected separately for medical schools at sampled institutions; 99 of the 137 institutions with medical schools were sampled.

The 1988 survey questionnaire collected data on research square footage and capital projects associated with research facilities by major science and engineering discipline, whereas the 1986 survey collected these data only in the aggregate. In addition, the current survey collected data on the square footage involved in repair/renovation and new construction projects by S/E field; these data were not collected in 1986. The 1986 survey collected cost information on repair, renovation, and construction in progress and work planned for the following 5 years. The current survey collected information on repair/renovation and new construction projects in the institution's previous two fiscal years (1986 and 1987) and work planned for FY 1988 and 1989. Finally, items concerning the adequacy of selected aspects of research facilities (infrastructure systems) were included in the current survey, but were not included in 1986.

The survey was conducted by mail, and extensive telephone follow-up was conducted to maximize the survey response rate. Considerable additional contact was necessary to resolve questions or problems with specific survey responses, in order to obtain the most complete and accurate information possible. The response rate to the survey was 90 percent for all universities and colleges, and 89 percent for medical schools. Rates of response were consistently high for all types of institutions.

Following the completion of data collection, additional site visits were conducted to discuss the data with the responding institutions and obtain insights that would assist in the analysis and interpretation of the data. (See **Appendix A, Technical Notes**, for additional detail on the study's methodology and a discussion of data considerations.)

Presentation of the Data and Organization of the Report

The 1988 Survey of Scientific and Engineering Research Facilities provides the most comprehensive national data base available to date on the status of these facilities. The detailed information will permit the analysis of changes in the status and condition of research facilities in the future. This report uses the data to present both quantitative and qualitative baselines on academic research facilities. Where appropriate, the findings of this survey are compared to the findings of the 1986 NSF survey on research facilities and to other previous facilities studies.

The first three chapters of findings provide quantitative information on academic research facilities. Chapter 2 presents the findings of the survey concerning the amount of research space currently available in science and engineering disciplines. Differences between institutional types, and between science and engineering disciplines are described. Chapter 3 discusses the costs and square footage associated with repair/renovation and new construction of research facilities for projects initiated in 1986 and 1987 and planned for 1988 and 1989. The sources of funds for these projects are presented in Chapter 4, with particular emphasis on the differences between public and private

[3] The universe file from which the sample was drawn was the 1983 survey of R&D expenditures, which represented the most recent universe survey of R&D spending at universities and colleges.

institutions. The status of private institutions relative to the limitation on outstanding tax-exempt bonds is also discussed in Chapter 4.

Chapter 5 presents the qualitative information collected in the survey, including the condition of research facilities, the adequacy of the amount of research space available, and the adequacy of selected infrastructure aspects of facilities. The findings concerning the condition and adequacy of the facilities are compared to capital project information provided in Chapter 3.

Chapter 6 provides a summary of findings for historically black colleges and universities. Chapter 7 compares the findings of the 1986 and 1988 surveys, to the extent to which comparisons can validly be made.

Appended to this report are an in-depth discussion of the 1988 study's design and methodology, and a comparison with the 1986 approach (Appendix A); a list of sampled institutions (Appendix B); a summary of information about the approval process for capital projects provided by the institutions (Appendix C); a copy of the survey questionnaire (Appendix D); and detailed statistical tables (Appendix E).

2. CURRENT AMOUNT OF RESEARCH SPACE

HIGHLIGHTS

- American universities and colleges reported a total of 114 million net assignable square feet (NASF) of science/engineering research space in 1988.
  - One-half (56.5 million square feet) was concentrated in the top 50 R&D performers, which reported a mean of 1.13 million square feet of research space per institution.
  - Other doctorate-granting institutions, those not in the top 50 in R&D, contain an additional 46 percent (52.5 million square feet) of all academic research space and have a mean of 217,000 square feet per institution.
  - Non-doctorate-granting institutions contain 4 percent (4.6 million square feet) of all academic research space, for a mean of 20,000 square feet per institution.
- Public institutions contain 73 percent (83.2 million square feet) of academic research space, while private institutions contain 27 percent (30.4 million square feet).
- Over 80 percent of all 1988 R&D space was concentrated in five disciplines: the biological (21 percent), medical (17 percent), agricultural (16 percent), and physical (14 percent) sciences, and engineering (14 percent).

Universities and colleges serve both instructional and research missions in the sciences and engineering. As a result, not all of the S/E space available at these institutions is dedicated to instructional activities; some is specifically assigned to research.

Institutions were asked to report both the total net assignable square feet (NASF) of S/E space in specified disciplines, and the total NASF used for separately budgeted organized research, as defined in OMB Circular A-21.[4]

The 524 universities and colleges in the survey universe contained an estimated total of 274 million square feet of assigned space in S/E disciplines in early 1988 (Appendix table 2-1). Of this, 114 million NASF, or 41 percent, were used for organized research (table 1). Most of this research space (96 percent) was located in doctorate-granting institutions.

Table 1. Number of institutions, amount of R&D space, and percent of total science/engineering (S/E) space used for R&D, by institution type and control: 1988

Institution type and control	Number of institutions	Amount of R&D space		
		Total	Mean per institution	As percent of total S/E space
		(sq. ft. in millions)	(sq. ft. in thousands)	
Total	524	114	217	41%
Doctorate-granting	292	109	374	45
Top 50 in R&D	50	57	1,130	53
Other	242	53	217	38
Non-doctorate-granting	232	5	20	16
Public	318	83	262	40
Doctorate-granting	190	80	422	43
In top 50 in R&D	31	39	1,258	51
Other	158	41	260	38
Non-doctorate-granting	129	3	24	15
Private	206	30	148	45
Doctorate-granting	103	29	281	49
In top 50 in R&D	19	18	921	60
Other	84	11	136	39
Non-doctorate-granting	103	2	15	17

Note: Details may not sum to totals because of rounding.

Reference: Appendix table 2-1.

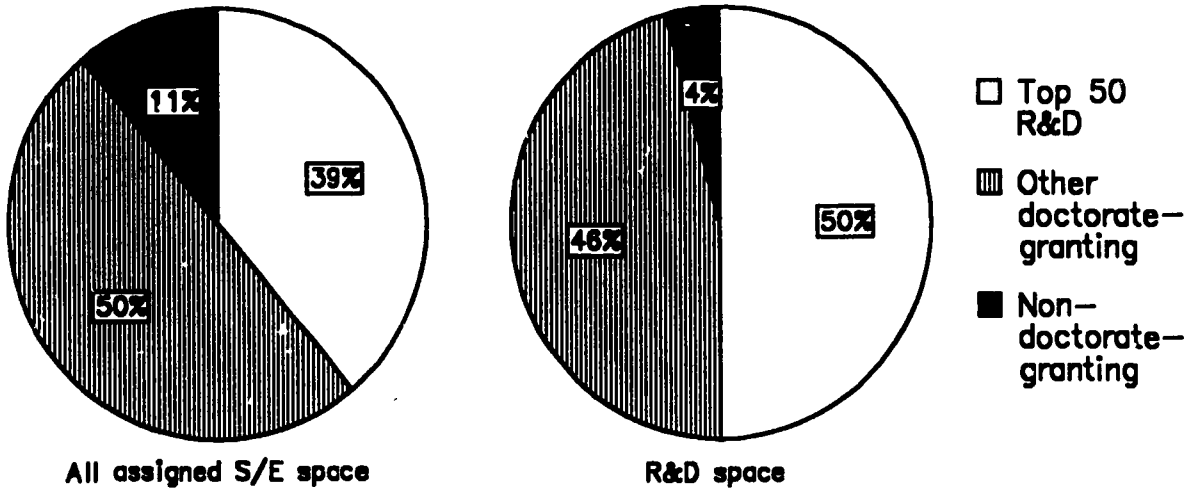
Source: National Science Foundation, SRS

The top 50 R&D performers, as determined from reported R&D expenditures for 1983, contain one-half of all academic research space, 56.5 million NASF.[5] The mean amount of R&D space for the top 50 R&D performers, all of which are doctorate-granting institutions, was much greater than the average across all other doctorate-granting institutions (1,130,000 NASF vs. 217,000 NASF). Non-

[4] This definition was used in recognition of the fact that the larger R&D institutions are required by the Federal Office of Management and Budget (OMB) to maintain information about their R&D space on the basis of the A-21 definition. The study intent was to take advantage of these existing institutional record systems, thereby minimizing response burden and improving standardization of reporting. All research square footage values are reported in net assignable square feet meeting the A-21 definition. The OMB definition of organized research appears in the Technical Notes, Appendix A.

[5] The top 50 R&D performers are used as an analytical group because they represent a significant proportion ($6.5 billion or 61 percent) of R&D expenditures and one-half of research NASF. In addition, they are the only institutional group which is comparable between NSF's 1986 and 1988 surveys. The reader should bear in mind that many institutions below the top 50 also have significant amounts of R&D expenditures and space.

Figure 1
Distribution of space assigned to science/engineering (S/E) disciplines, by institution type: 1988



Reference: Appendix table 2-1
Source: National Science Foundation, SRS

doctorate-granting institutions had the smallest average amount of R&D space (20,000 NASF per institution).

The percentage of S/E space that is used for organized research is also considerably higher at the top 50 institutions (53 percent) than at other doctorate-granting institutions (38 percent) or at non-doctorate-granting institutions (16 percent). Consequently, the top 50 institutions have an even larger share of all academic R&D space (50 percent) than they do of all academic S/E space (39 percent), and non-doctorate-granting institutions have a smaller fraction of total R&D space (4 percent) than of overall S/E space (11 percent) (figure 1). These institution type differences might have been somewhat less pronounced if the survey had included all space used for S/E research, rather than just space used for organized research, as defined in OMB Circular A-21. Anecdotal information from visits to selected institutions suggests that the A-21 definition encompasses the great majority of space actually used for research at the largest R&D institutions, but for smaller institutions -- especially for non-doctorate-granting universities and colleges -- significant amounts of research are not separately budgeted and take place in space that does not qualify under A-21. However, even if all non-doctorate-granting institutions in the study universe allocated fully as much of their total S/E space to research as do the 50 most intensively research-oriented institutions in the Nation, the 232 non-doctorate-granting institutions would collectively account for no more than 11 percent of all academic R&D space.

The mean amount of R&D space per institution for the top 50 R&D institutions in the Nation (1,130,000 NASF) is about 9 percent higher than the amount found 2 years earlier in the 1986 NSF research facilities survey (1,032,000 NASF). The two studies used comparable definitions of both "R&D space" and "top 50 institutions", and it appears that the difference between the two estimates reflects real, net expansion of R&D space at these institutions over the 2-year interval between the studies.[6]

In each major institution-type category (i.e., top 50 in R&D, other doctorate-granting, and non-doctorate-granting), the mean amount of R&D space per institution is considerably larger at public than at private institutions, in spite of the fact that private institutions allocate somewhat higher proportions of their S/E space for organized research use than do public institutions -- overall and in each of the three type categories (table 1).

[6]This is the only subgroup for which the two surveys are comparable, since the 1986 survey excluded all non-doctorate-granting institutions and about one-half of all doctorate-granting institutions below the top 50.

Although nearly all 524 institutions encompassed by this survey maintain R&D space in some disciplines, few have research programs in all S/E disciplines. (In later sections of this report, statistics on the condition and other characteristics of research facilities, by discipline, are limited to those institutions that report some R&D space in the discipline.) Research programs in the biological sciences are most widely represented: 90 percent of all institutions (and 100 percent of the top 50) reported some space for organized research in this area (table 2). Other disciplines with comparatively widespread representation are the physical sciences, which have research space at 85 percent of all surveyed institutions, psychology (77 percent), and the social sciences (69 percent). All other disciplines have organized research space at less than two-thirds of all research institutions. Institutions least often reported space for organized research in the agricultural sciences (19 percent, nearly all of which was in public institutions) or in the category entitled "other sciences, not elsewhere classified (n.e.c.)" (18 percent). This "other sciences" category consists primarily of non-departmental, interdisciplinary facilities that are dedicated entirely to research and are found predominantly at the larger R&D institutions.

Although present at comparatively few institutions, the agricultural sciences and "other sciences" both have relatively large percentages of their total space assigned for R&D use: 58 percent and 72 percent, respectively (table 3).

Table 2. Percent of institutions with any assigned R&D space in science/engineering disciplines, by discipline and institution type: 1988

Disciplines	Institution type			
	Total	Doctorate-granting		Non-doctorate-granting
		Top 50 in R&D	Other	
Total	100%	100%	100%	100%
Engineering	55	88	69	33
Physical sciences	85	96	77	91
Environmental sciences	57	86	65	41
Mathematics	61	86	60	56
Computer science	64	80	55	69
Agricultural sciences	19	48	20	10
Biological sciences	90	100	83	94
Medical sciences	49	92	64	24
Psychology	77	92	71	80
Social sciences	69	92	71	62
Other sciences, n.e.c.	18	48	25	4

Reference: Appendix table 2-2.

Source: National Science Foundation, SRS.

Table 3. Percent of assigned science/engineering space that is used for R&D, by discipline and institution type: 1988

Disciplines	Institution type			
	Total	Doctorate-granting		Non-doctorate-granting
		Top 50 in R&D	Other	
Total	41%	53%	36%	16%
Engineering	39	50	36	12
Physical sciences	46	59	46	19
Environmental sciences	51	64	46	15
Mathematics	15	19	18	6
Computer science	29	41	28	16
Agricultural sciences	58	73	50	21
Biological sciences	53	67	51	17
Medical sciences	29	37	25	9
Psychology	34	45	36	18
Social sciences	21	28	19	9
Other sciences, n.e.c.	72	77	75	20

Reference: Appendix table 2-3.

Source: National Science Foundation, SRS.

At the other extreme, mathematics has only a small fraction of its assigned space allocated for R&D use (15 percent), as do the social sciences (21 percent). These field differences have implications for later findings on the construction and repair/renovation of research facilities. Since institutions were asked to report only the portion of construction or repair/renovation projects that affects R&D space, the percentages shown in table 3 indicate that the prorated, or R&D-related, component will be a comparatively small fraction of the total space and cost of all S/E facilities, and this fraction varies by institutional type and discipline.

Collectively, the three life science disciplines account for over one-half (54 percent) of all academic R&D space: the biological sciences (21 percent), the medical sciences (17 percent), and the agricultural sciences (16 percent) (table 4). Engineering and the physical sciences each have 14 percent shares of all academic R&D space, and the remaining disciplines contain less than 10 percent each. These findings closely parallel the findings of the most recent NSF survey of academic R&D expenditures, concerning the distribution of R&D expenditures among disciplines.[7] The only discipline for which there is a substantial difference between the two is the agricultural

[7] Academic Science/Engineering R&D Funds: Fiscal Year 1986 (Detailed Statistical Tables), National Science Foundation, 1988 (Publication Number NSF 88-312).

Table 4. Distribution of R&D space by discipline and institution type: 1988

Discipline	Institution type			
	Total	Doctorate-granting		Non-doctorate-granting
		Top 50 in R&D	Other	
	(percent of institutions' R&D space)			
Total	100%	100%	100%	100%
Engineering	14	15	13	12
Physical sciences	14	13	14	29
Environmental sciences	6	6	5	4
Mathematics	1	0	1	1
Computer science	1	1	1	4
Agricultural sciences	16	18	15	6
Biological sciences	21	20	23	22
Medical sciences	17	17	19	2
Psychology	3	2	3	9
Social sciences	3	3	3	7
Other sciences, n.e.c.	4	4	4	2

Note: Percents may not sum to 100 because of rounding

Reference: Appendix table 2-3.

Source: National Science Foundation, SRS.

sciences, which have a larger share of R&D space (16 percent) than of R&D expenditures (10 percent).

The three types of institutions have somewhat different distributions of research space across disciplines. Thus, the physical sciences, computer science, psychology and the social sciences occupy comparatively large fractions of the R&D space at non-doctorate-granting institutions, while the environmental, agricultural, and medical sciences are more prominent within doctorate-granting institutions (table 4). However, the biological sciences have the single largest share of institutions' total R&D space, overall (21 percent) and among doctorate-granting institutions.

3. NEW CONSTRUCTION AND REPAIR/RENOVATION OF RESEARCH FACILITIES

HIGHLIGHTS

- Institutions' expected spending for construction of research facilities totaled $5.5 billion during the 1986-1989 period and grew from $2.1 billion in 1986-87 to $3.4 billion in 1988-89, an average increase of about 30 percent per year. This remarkable increase is partly attributable to an increase in the amount of research space under construction, which grew by 10 percent per year over this period. More importantly, the average construction cost per square foot of research space grew by 20 percent per year over this period. This suggests that recent increases in spending for construction of research facilities are being driven more by rapidly changing technical and regulatory requirements for science/engineering research space than by institutions' desires to expand the quantity of their research space.

- Institutions' expected spending for facilities repair/renovation declined somewhat, from $863 million in 1986-87 to $777 million in 1988-89.

- The top 50 R&D performers plan to spend a total of $3.0 billion (an average of $60.9 million per institution) for research-related construction and an additional $885 million ($17.7 million per institution) for facilities repair/renovation over the period 1986-89.

- Doctorate-granting institutions below the top 50 reported actual and planned spending of $2.1 billion for construction of R&D facilities in the period 1986-89, an average of $8.9 million per institution. Expenditures for repair/renovation are expected to total $674 million, or $2.8 million per institution.

- During the 1985-89 period, non-doctorate-granting institutions plan to spend $271 million (an average of $1.2 million per institution) for new construction and $81 million ($349,000 per institution) for repair/renovation.

- On a per-institution basis, private institutions within the top 50 reported considerably higher spending levels than their public-sector counterparts, for both construction and repair/renovation of research facilities. The reverse was true among institutions not in the top 50 in R&D (both doctorate-granting and non-doctorate-granting), where mean facilities spending levels were higher at public institutions than at private ones.

- Over one-half of all facilities-related spending (construction plus repair/renovation) was concentrated in two disciplines: the medical sciences (29 percent) and the biological sciences (21 percent).

This chapter discusses the scope and costs of institutions' projects to construct new R&D space or to repair or renovate existing R&D space. The data are limited to major projects, those with total R&D-related costs (across all affected disciplines) of $100,000 or more. For projects involving construction or repair/renovation of buildings used only partly for organized R&D, institutions were instructed to prorate their estimates of total project cost and square feet to reflect only the R&D component. Data were collected separately for projects started in fiscal years (FY) 1986 and 1987, and for those planned to begin in the 2-year period FY 1988-89. For simplicity, references to the period in which the construction or repair/renovation project begins frequently omit the notation "FY"; it is understood that all such dates refer to the institutions' fiscal years.

Basic quantitative findings concerning numbers of institutions with recent or planned construction or repair/renovation projects, the net assignable square feet (NASF) of R&D space involved, and the estimated total cost at completion for the R&D component of the projects are presented in Appendix tables 3-1 to 3-8. These data are summarized below.

Construction of New R&D Space, 1986-89

Extent of Construction Activity

In any given year, relatively few institutions break ground for major projects to construct new facilities for S/E research.[8] Only 92 doctorate-granting institutions (32 percent) and 36 non-doctorate-granting institutions (16 percent) began any such projects in 1986, and the proportions were even lower in 1987: 32 percent of doctorate-granting institutions and 11 percent of non-doctorate-granting institutions (Appendix table 3-1). However, across the entire 4-year period covered by this

[8] Construction is defined as new building or addition to an existing building. Total project costs include planning, construction, and fixed equipment for the building and associated infrastructure.

Table 5. Percent of institutions starting any projects to construct new science/engineering R&D space, by institution type and control and year of project start: 1986-89*

Institution type and control	Year of construction project start		
	1986 or 1987 (begun)	1988 or 1989 (planned)	1986 to 1989 (4 yr. total)
Total	37%	43%	59%
Doctorate-granting	46	61	76
Top 50 in R&D	80	80	94
Other	39	57	72
Non-doctorate-granting	25	21	38
Public	44	56	73
Doctorate-granting	54	70	85
In top 50 in R&D	90	87	97
Other	47	68	84
Non-doctorate-granting	29	36	53
Private	25	23	39
Doctorate-granting	31	45	57
In top 50 in R&D	63	68	89
Other	25	38	50
Non-doctorate-granting	16	2	20

*Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D-related space.

Reference: Appendix tables 3-1 and 2-1.

Source: National Science Foundation, SRS.

study (1986-89), over three-quarters (76 percent) of all doctorate-granting institutions, including 94 percent of the top 50 R&D performers, plan at least one major project to construct new research space (table 5). Among non-doctorate-granting institutions, only 38 percent plan such projects; the majority of these institutions (62 percent) do not plan any new construction of R&D facilities at any time during this 4-year period.

About three-fourths (73 percent) of public-sector institutions anticipate some new construction of R&D facilities in the period 1986-89, a much higher percentage than was found for private institutions: 39 percent. Substantial differences in the direction of more widespread construction at public than at private institutions were found for each time period and in every institution-type category studied (table 5). This is consistent with the findings of NSF's 1986 facilities survey, in which 72 percent of public universities, but only 44 percent of private schools, reported construction activity in progress.

Since construction projects often affect only one or two disciplines, the numbers of institutions doing or planning new construction in any particular S/E discipline in any particular year are generally only a fraction of those with ongoing research programs in the discipline. At the extreme, only 4 percent of institutions with R&D space in mathematics reported any recent or planned construction of new space in that field. Construction activity was also very limited in psychology (7 percent of all institutions) and the social sciences (10 percent) (table 6). The discipline with the most widespread construction activity was the agricultural sciences (60 percent of institutions with organized research in that field), but this is something of a special case because agricultural research is so heavily concentrated in a small number of (often large, usually public) institutions. Among the remaining disciplines, the medical sciences and engineering stand out as ones with relatively widespread construction activity over the 1986-89 period (43 percent and 40 percent, respectively, of applicable institutions).

Amount of New R&D Space under Construction

Construction projects begun in 1986 were estimated to provide 4.7 million net assignable square feet (NASF) of

Table 6. Percent of institutions with any recent or planned projects to construct new R&D space, by discipline and institution type: 1986-89*

Disciplines	Institution type			
		Doctorate-granting		Non-doctorate-granting
	Total	Top 50 in R&D	Other	
Total	59%	94%	72%	38%
Engineering	40	73	29	46
Physical sciences	23	46	25	16
Environmental sciences	19	21	16	24
Mathematics	4	9	5	1
Computer science	14	23	16	11
Agricultural sciences	60	71	65	38
Biological sciences	31	54	36	22
Medical sciences	43	70	48	5
Psychology	7	13	5	8
Social sciences	10	4	10	11
Other sciences, n.e.c.	24	33	26	<1

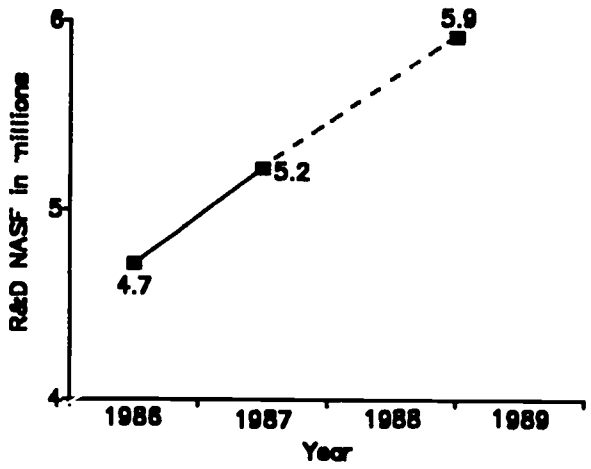
*Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D-related space. The base of the percentage is the estimated number of institutions with any R&D space in the discipline in 1988.

Reference: Appendix tables 3-1a and 2-2.

Source: National Science Foundation, SRS.

Figure 2

Total R&D–related net assignable square footage of recent and planned construction projects, by year of project start: 1986–89*



* Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D related space.
Note: "Annualized" estimate for the two year period 1988–89 is one–half the reported total for this period.
Source: National Science Foundation, SRS

additional research space in S/E disciplines;[9] projects begun in 1987 were expected to produce 5.2 million NASF of new R&D space; and projects planned for 1988 and 1989 were expected to produce a total of 11.8 million more NASF (or an average of 5.9 million NASF per year over this period). These totals form a close-to-linear progression implying an annual increase in amount of construction of about 10 percent per year from 1986 to 1989 (figure 2).

Expressed as a percentage of existing (i.e., 1988) R&D square footage, new construction begun in 1986 or 1987 will produce the equivalent of 9 percent of current academic R&D space, and projects planned for 1988 and 1989 will contribute another 10 percent. Among public institutions, those in the non-doctorate-granting category anticipate a larger relative amount of R&D space from all 1986-89 construction projects (the equivalent of 43 percent of their existing space) than do doctorate-granting institutions, both those outside the top 50 (20 percent) and those in the top 50 (17 percent) (table 7). The reverse is the case for private institutions, where the non-doctorate-granting institutions anticipate less construction-generated space (the equivalent of 13 percent of existing research space) than doctorate-granting institutions, whether in the top 50 (17 percent) or not in the top 50 (22 percent). Somewhat surprisingly, in view of earlier findings that comparatively few private institutions are engaged in any recent or planned construction, there are essentially no differences between public and private sectors in the relative amount of research space to be produced by new construction in 1986-87 or in 1988-89 at doctorate-granting institutions (table 7).

As noted earlier, some of the research space being generated through new construction is intended to replace existing facilities and will not produce a net expansion in total academic R&D space. The only information available about net change in academic research space comes from a comparison between the total amount of organized research space reported by the top 50 institutions in the current study and the amount reported 2 years earlier in the 1986 NSF research facilities study: as noted in Chapter 2, the current

Table 7. Total net assignable square feet (NASF) of R&D space to be created by recent and planned construction as a percentage of existing R&D space, by institution type and year of project start: 1986-89*

Institution type and control	Year of construction project start		
	1986 or 1987 (begun)	1988 or 1989 (planned)	1986 to 1989 (4 yr. total)
Total	9%	10%	19%
Doctorate-granting	8	10	19
Top 50 in R&D	8	9	17
Other	9	12	20
Non-doctorate-granting	22	11	33
Public	9	11	19
Doctorate-granting	8	10	18
In top 50 in R&D	8	9	17
Other	8	12	20
Non-doctorate-granting	27	16	43
Private	9	10	19
Doctorate-granting	8	11	19
In top 50 in R&D	7	10	17
Other	11	12	22
Non-doctorate-granting	12	1	13

*Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D-related space.

Note: Details may not sum to totals because of rounding.

Reference: Appendix tables 3-2 and 2-1.

Source: National Science Foundation, SRS.

[9] This additional research space created through new construction does not necessarily represent a net expansion in the total amount of available research space. In some cases, the new facilities are intended to replace, not to supplement, older ones.

Table 8. Total net assignable square feet (NASF) of R&D space to be created by recent and planned construction as a percentage of existing R&D space, by discipline and year of project start: 1986-89*

Disciplines	Year of construction project start		
	1986 or 1987	1988 or 1989 (planned)	1986 to 1989 (4 yr. total)
Total	9%	10%	19%
Engineering	15	12	27
Physical sciences	5	11	16
Environmental sciences	6	7	13
Mathematics	1	5	6
Computer science	17	15	32
Agricultural sciences	9	5	13
Biological sciences	7	10	17
Medical sciences	10	17	27
Psychology	4	3	7
Social sciences	6	7	13
Other sciences, n.e.c.	14	15	28

*Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D-related space.

Note: Details may not sum to totals because of rounding.

Reference: Appendix tables 3-4 and 2-2.

Source: National Science Foundation, SRS.

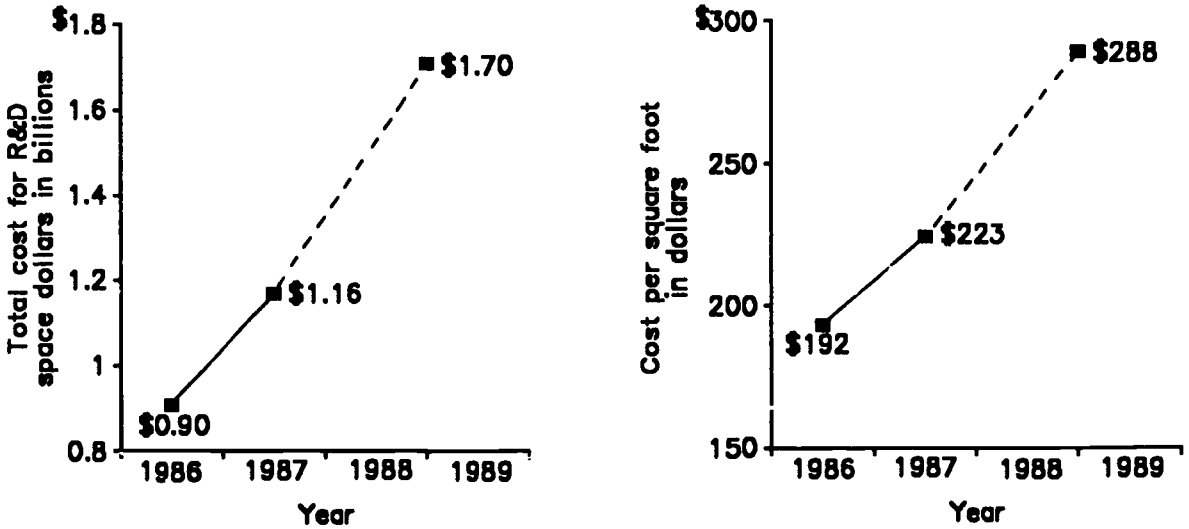
amount is 9 percent higher than the amount reported in 1986. If the amount of research space to be produced by construction projects planned for 1988 and 1989 (i.e., 10 percent of existing space) is viewed as an upper limit on net expansion, it appears that the net growth in R&D space in 1988-89 for the top 50 institutions will be no greater than the (9 percent) growth seen in 1986-87.

Computer science is the discipline with the greatest relative amount of construction activity in 1986-89, with projects involving the equivalent of 32 percent of existing research space. Comparatively large amounts of construction activity were also found for engineering (27 percent of existing research space), medical sciences (27 percent), and other (i.e., interdisciplinary) sciences (28 percent) (table 8). Comparatively little construction activity was found for mathematics (where all recent and planned projects involved the equivalent of 6 percent of current space) and psychology (7 percent of existing space).

Cost of New R&D Space under Construction

Aggregate costs for the R&D-related components of all new facilities construction projects begun in 1986 are estimated

Figure 3
R&D-related total cost and cost per square foot of recent and planned construction projects, by year of project start: 1986-89*



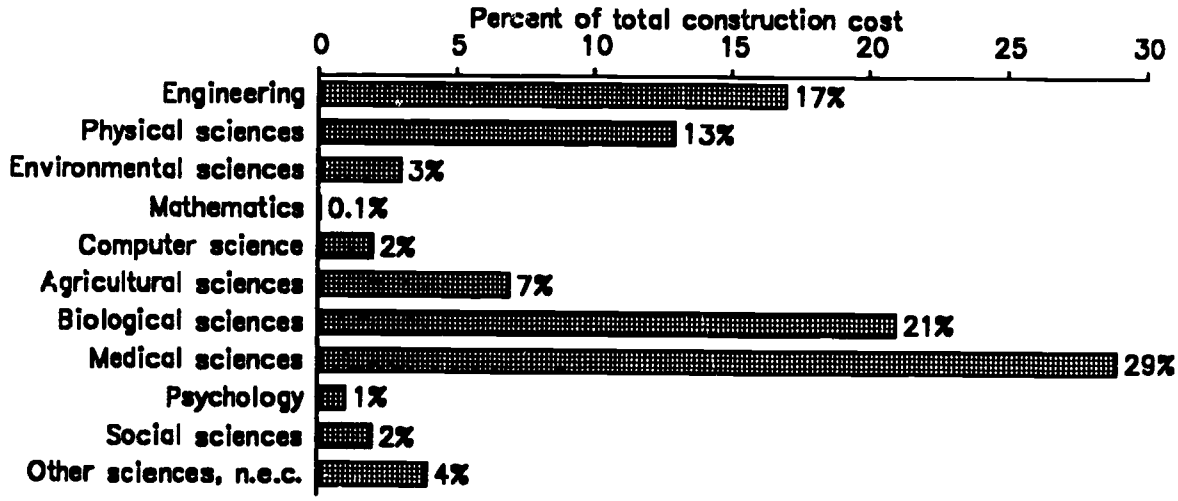
* Findings are limited to projects with estimated total cost at completion of $100,000 or more R&D related space.
Note: "Annualized" estimates for the two year period 1988-89 are one-half the reported totals for this period.
Source: National Science Foundation, SRS

to total $900 million; the estimated cost for construction projects begun in 1987 is $1.16 billion; and the estimated cost for projects planned for 1988 and 1989 is $3.4 billion, or $1.7 billion per year over this period. As found earlier for estimates of amount of space under construction, these estimates form a nearly linear progression. However, while the amount of space under construction increased at about 10 percent per year over the period 1986-89, the estimated cost of that same construction increased at a pace of 30 percent to 35 percent per year. The reason the rate of increase in total construction cost is so much higher than the increase in the amount of space under construction is that the unit cost of new construction (the cost per square foot) grew appreciably, from $192 per NASF in 1986 to $288 per NASF in 1988-89 (figure 3). This represents an average annual increase of about 20 percent per year over the period 1986-89.

Construction cost increases of this magnitude, which are far above the rate of inflation, suggest that we may be in a period of changing technical and regulatory requirements for academic research space, as institutions seek to respond to requirements for increasingly sophisticated (and costly) animal quarters, biohazard containment safeguards, toxic waste disposal facilities, etc. Consistent with this analysis, fully half (50 percent) of all recent and planned R&D construction costs in 1986-89 are in two disciplines that are both heavily impacted by such increased qualitative requirements for research facilities: the medical sciences (which account for 29 percent of all construction costs) and the biological sciences (21 percent) (figure 4).

On a per-institution basis, the mean estimated cost of all R&D-related construction projects begun or planned in 1986-89 is $60.9 million for the top 50 R&D institutions, $8.9 million for other doctorate-granting institutions, and $1.2 million for non-doctorate-granting institutions (table 9). Estimated mean construction costs at private institutions that are among the top 50 R&D performers are $70.4 million per institution, as compared to $55.1 million for their public sector counterparts. For institutions not among the top 50, however, average construction costs are expected to be lower at private than at public institutions. The difference is especially pronounced among non-doctorate-granting institutions: those in the public sector plan to spend an average of $1.9 million per institution, as compared to an average of only $300,000 per institution for private universities and colleges.

Figure 4
Distribution by discipline of the total cost of recent and planned projects to construct new R&D space: 1986–89*



* Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D related space.
Reference: Appendix table 3–4
Source: National Science Foundation, SRS

Table 9. Mean cost per institution of projects to construct new R&D space, by institution type and control and year of project start: 1986-89*

Institution type and control	Year of construction project start		
	1986 or 1987 (begun)	1988 or 1989 (planned)	1986 to 1989 (4 yr. total)
	(dollars in millions)		
Total	$3.9	$6.5	$10.4
Doctorate-granting	6.5	11.3	17.8
Top 50 in R&D	23.8	37.1	60.9
Other	2.9	5.9	8.9
Non-doctorate-granting	0.7	0.5	1.2
Public	4.3	6.7	10.9
Doctorate-granting	6.5	10.6	17.1
In top 50 in R&D	24.5	30.5	55.1
Other	3.0	6.7	9.7
Non-doctorate-granting	1.0	0.8	1.9
Private	3.4	6.2	9.6
Doctorate-granting	6.5	12.4	18.9
In top 50 in R&D	22.5	47.9	70.4
Other	2.9	4.4	7.3
Non-doctorate-granting	0.3	<0.1	0.3

*Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D-related space. Means are based on all institutions with some assigned R&D space.

Note: Details may not sum to totals because of rounding.

Reference: Appendix tables 3-2 and 2-1.

Source: National Science Foundation, SRS.

Repair/Renovation of Research Facilities, 1986-89

Extent of Repair/Renovation Activity

Sixty percent of all institutions in the study universe plan at least one major project of $100,000 or more to repair or renovate[10] research facilities over the 4-year period 1986-89 (table 10). This is very similar to the 59 percent figure noted earlier (table 5) with respect to facilities construction activity. The pattern of overall differences between types of institutions in repair/renovation activity is also very similar to the pattern for construction activity. For example, there is more frequent activity at doctorate-granting institutions than at non-doctorate-granting universities and colleges; and more repair/renovation activity at public than at private institutions of the same type.

Differences among disciplines with respect to frequency of repair/renovation projects also are generally similar in kind, although somewhat smaller in degree, in comparison to those seen earlier regarding frequency of new construction (compare table 11 and table 6). Thus, while discipline differences in new construction ranged from 4 percent to 60 percent of institutions with research programs in the discipline, the differences in extent of repair/renovation ranged more narrowly, from 10 percent to 53 percent.

The major difference between the two patterns is that, while the number of institutions involved in facilities construction projects increased steadily from 1986 to 1987 to 1988-89, the number involved in repair/renovation projects declined from 289 (55 percent) in 1986-87 combined to 230 (44 percent) in 1988-89 combined (table 10 and Appendix table 3-5).

Table 10. Percent of institutions performing major repair/renovation of science and engineering R&D facilities, by institution type and control and year: 1986-89*

Institution type and control	Year of construction project start		
	1986 or 1987 (begun)	1988 or 1989 (planned)	1986 to 1989 (4 yr. total)
Total	55%	44%	60%
Doctorate-granting	77	65	81
Top 50 in R&D	96	98	100
Other	73	59	77
Non-doctorate-granting	28	16	32
Public	66	51	70
Doctorate-granting	86	68	88
In top 50 in R&D	94	97	100
Other	85	63	87
Non-doctorate-granting	36	26	43
Private	38	32	43
Doctorate-granting	60	59	68
In top 50 in R&D	100	100	100
Other	51	50	61
Non-doctorate-granting	17	5	18

*Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D-related space.

Reference: Appendix tables 3-5 and 2-1.

Source: National Science Foundation, SRS.

[10] Repair/renovation includes the repair of deteriorated condition, capital improvements, upgrading, conversion, etc. Total project costs include planning, construction, and fixed equipment for the building and associated infrastructure.

Table 11. Percent of institutions performing major repair/renovation of existing R&D space, by discipline and year: 1986-89*

Disciplines	Year of repair/renovation		
	1986 or 1987	1988 or 1989 (planned)	1986 to 1989 (4 yr. total)
Total	55%	44%	60%
Engineering	41	33	53
Physical sciences	22	22	32
Environmental sciences	14	10	18
Mathematics	8	4	10
Computer science	14	7	16
Agricultural sciences	34	27	47
Biological sciences	30	24	37
Medical sciences	34	30	39
Psychology	9	5	12
Social sciences	8	4	11
Other sciences, n.e.c.	18	15	28

*Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D-related space. The base of the percentage is the estimated number of institutions with any R&D space in the discipline in 1988.

Reference: Appendix tables 3-7 and 2-2.

Source: National Science Foundation, SRS.

This decline in the number of institutions planning major facilities repair/renovation projects may reflect some inherent problems in projections of short-term future need for such projects. Thus, while construction projects are usually planned far in advance, the need for repair/renovation projects may sometimes arise suddenly and unpredictably. In reporting their plans for 1988-89, some institutions may have underestimated the likelihood that they will need at least one major repair/renovation project during this period. There may also be some cases where construction activity aimed at replacing obsolete research facilities is expected to produce significant reductions in future repair/renovation costs.

Amount of Existing R&D Space Under Repair/Renovation

An estimated 6.6 million NASF of research space was repaired/renovated in 1986, and an estimated 7.1 million NASF was repaired/renovated in 1987. These figures are both somewhat higher than the amounts of new research space constructed during the same 2 years (4.7 million and 5.2 million NASF, respectively). For the period 1988-89, the average annual amount of planned repair/renovation dropped to 4.8 million NASF, while the amount of planned new construction increased to 11.8 million NASF. As suggested above, this disparity could be essentially a reporting problem (institutions systematically underestimating future needs for repair/renovation but not their short-term plans for new construction), or it might reflect a real shift away from repair/renovation and toward new construction among institutions needing to expand or upgrade their research facilities.[11] To some extent, the decline in the square feet involved in repair/renovation projects is a function of greater unit cost as well as the decline in total repair/renovation cost.

Differences among **institution types** in the extent of recent and planned repair/renovation are considerably less pronounced, and are also less consistent over time, than the

Table 12. Percent of existing R&D space undergoing major repair/renovation, by institution type and control and year: 1986-89*

Institution type and control	Year of construction project start		
	1986 or 1987 (begun)	1988 or 1989 (planned)	1986 to 1989 (4 yr. total)
Total	12%	9%	21%
Doctorate-granting	12	9	21
Top 50 in R&D	10	9	19
Other	14	8	23
Non-doctorate-granting	13	4	17
Public	11	8	19
Doctorate-granting	10	8	19
In top 50 in R&D	7	7	14
Other	14	9	23
Non-doctorate-granting	14	5	20
Private	16	10	26
Doctorate-granting	16	10	27
In top 50 in R&D	17	12	30
Other	15	7	22
Non-doctorate-granting	10	1	11

*Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D-related space.

Note: Details may not sum to totals because of rounding.

Reference: Appendix tables 3-8 and 2-1.

Source: National Science Foundation, SRS.

[11] The next cycle of the NSF research facilities study will provide information about the amounts of new construction and repair/renovation that actually occur during the 1988-89 period and will make it possible to determine which of these two possibilities is correct.

differences noted earlier regarding new construction (table 12).

Differences among disciplines in extent of recent and planned repair/renovation are both more pronounced and more consistent over time than the differences among institution types (table 13). One interesting finding is that the two disciplines with the greatest dollar amount of new construction in 1986-89 also anticipate repair/renovation of comparatively large percentages of their existing research space over the same period (30 percent of existing medical sciences research space, and 26 percent of existing space in the biological sciences).

Cost of Repair/Renovation of Existing Research Space

Estimated total annual costs of major projects to repair/renovate academic R&D space declined somewhat from 1986-87 to 1988-89. The change was comparatively modest, however, since a decline in the anticipated total square footage of space to undergo repair or renovation was

Table 13. Percent of existing R&D space undergoing major repair/renovation, by discipline and year: 1986-89*

Disciplines	Year of repair/renovation		
	1986 or 1987	1988 or 1989 (planned)	1986 to 1989 (4 yr. total)
Total	12%	9%	21%
Engineering	17	9	26
Physical sciences	11	9	20
Environmental sciences	6	7	13
Mathematics	5	5	10
Computer science	13	6	19
Agricultural sciences	4	3	6
Biological sciences	16	11	26
Medical sciences	17	13	30
Psychology	8	3	12
Social sciences	5	3	8
Other sciences, n.e.c.	11	8	19

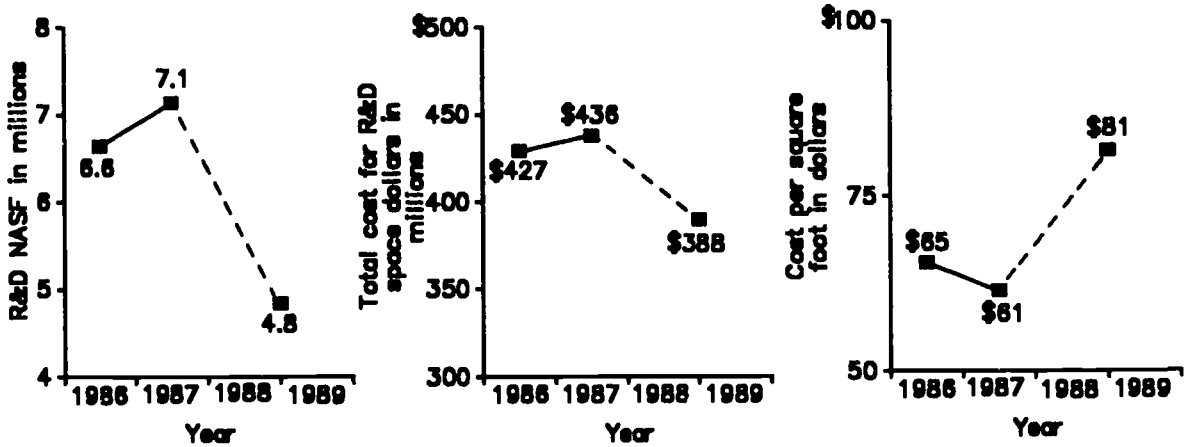
*Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D-related space.

Note: Details may not sum to totals because of rounding.

Reference: Appendix tables 3-8 and 2-3.

Source: National Science Foundation, SRS.

Figure 5
Estimated total square footage, cost, and cost per square foot of projects for repair/renovation of R&D space, by year: 1986–89*



* Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D related space.
Note: "Annualized" estimates for the two year period 1988–89 are one–half the reported totals for this period.
Source: National Science Foundation, SRS

accompanied by a partly offsetting increase in the average expected repair/renovation cost per square foot (figure 5).

Institution-level comparisons on total cost in 1986-89 of research facility repair/renovation again reveal greater differentiation among types of private institutions than among the same categories of public institutions. Thus, private institutions that are among the top 50 R&D performers spent much more for facility repair and renovation ($28.9 million per institution) than their public institution counterparts ($10.8 million per institution), while the reverse was true in comparing private non-doctorate-granting institutions ($107,000 per institution) to their public sector counterparts ($550,000 per institution) (table 14).

Anticipated repair/renovation spending is heavily concentrated in four disciplines that together account for 84 percent of the total over the period 1986-89: the medical (30 percent), biological (24 percent), and physical (14 percent) sciences, and engineering (16 percent) (figure 6). Differences among disciplines in expenditures for repair/renovation of research facilities are very similar to the differences shown earlier in the comparative amounts of existing research space in the various disciplines (see table 4). The only substantial disparity is for the agricultural sciences, which have 16 percent of all reported research space, but which account for only 3 percent of all reported repair/renovation spending.

Table 14. Mean cost per institution for repair/renovation of existing R&D space, by institution type and control and year: 1986-89*

Institution type and control	Year of repair/renovation		
	1986 or 1987 (begun)	1988 or 1989 (planned)	1986 to 1989 (4 yr. total)
	(dollars in thousands)		
Total	$1,647	$1,483	$3,130
Doctorate-granting	2,801	2,538	5,339
Top 50 in R&D	8,800	8,900	17,700
Other	1,562	1,223	2,785
Non-doctorate-granting	194	155	349
Public	1,381	1,399	2,780
Doctorate-granting	2,116	2,158	4,274
In top 50 in R&D	4,548	6,258	10,806
Other	1,658	1,367	3,025
Non-doctorate-granting	287	264	550
Private	2,058	1,612	3,670
Doctorate-granting	4,029	3,214	7,243
In top 50 in R&D	15,737	13,211	28,947
Other	1,381	952	2,333
Non-doctorate-granting	87	19	107

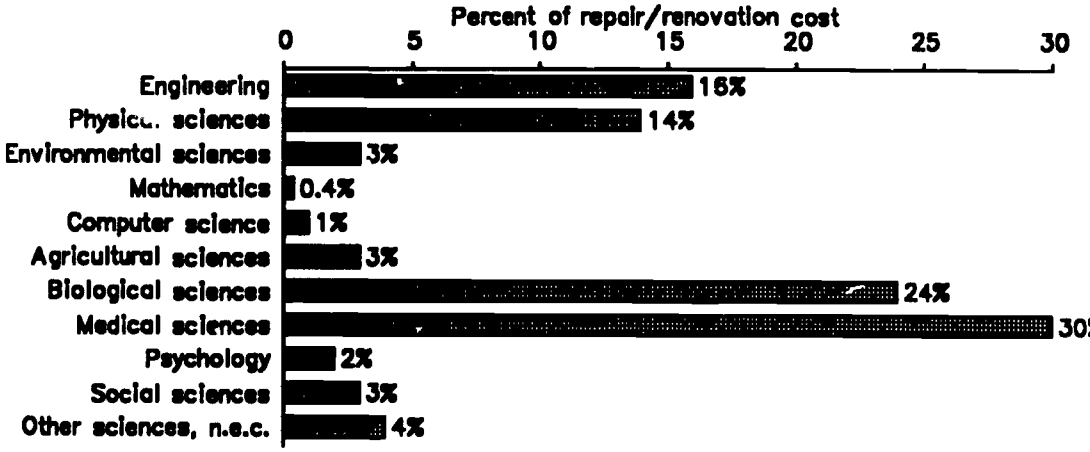
*Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D-related space.

Note: Details may not sum to totals because of rounding.

Reference: Appendix tables 3-6 and 2-1.

Source: National Science Foundation, SRS.

Figure 6
Distribution by discipline of the total cost of recent and planned repair/renovation of existing R&D space: 1986–89*



* Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D related space.
Reference: Appendix table 3–8
Source: National Science Foundation, SRS

4. SOURCES OF FUNDS FOR RESEARCH FACILITIES PROJECTS

HIGHLIGHTS

- Funds for new facilities **construction** come primarily from three sources: State/local governments, private sources, and tax-exempt bonds. Major sources of funding for **repair/renovation** include institutional funds, State/local governments, and tax-exempt bonds. The proportion of Federal support for construction is about 7 percent and the Federal share of repair/ renovation is 3 percent to 5 percent.

- Public institutions secure a greater proportion of funds from State/local governments, whereas private schools rely more on private sources and tax-exempt bonds.

- Tax-exempt bonds are the principal means of debt financing used for construction and repair/renovation. The debt financing of all reported projects (1986 through 1989) totals approximately $1.4 billion, about 20 percent of the total costs of all reported projects.

- One-tenth of private institutions have reached the legislative cap of $150 million on tax-exempt bonds. Another 4 percent anticipate reaching the cap in the next 2 years. Among the 19 private institutions in the top 50, 11 have reached the cap, and 3 more expect to do so within 2 years.

- Of the 15 private medical schools among the top 50 R&D institutions, 11 have reached the bond limit, and 2 expect to within the next 2 years.

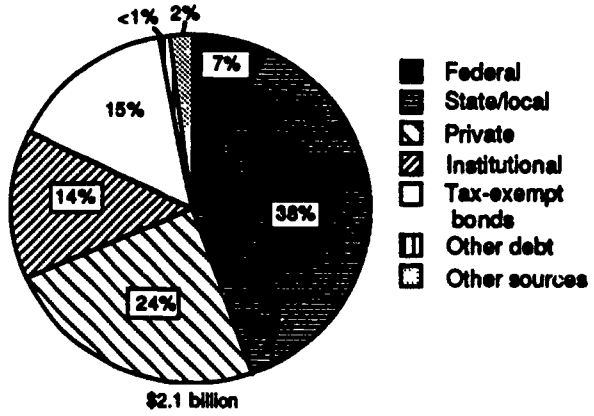
Institutions use a variety of sources and mechanisms for the funding of facilities projects.[12] The discussion in this chapter includes various funding sources (e.g., Federal, State/local, private, institutional), as well as the use of debt financing (tax-exempt bonds and other debt). The reader should bear in mind that debt financing is a separate mechanism which results in obligations that must be repaid by the institutions.

Sources of Funds for Recent Research Facilities Projects

New Construction: 1986 and 1987

The costs of new construction in 1986 and 1987, about $2.1 billion, were funded from a number of sources (figure 7 and table 15). The largest source was State/local governments, which provided 38 percent of the funds for these projects, about $783 million. Private sources provided the next largest proportion of funds, 24 percent ($487 million). Institutional funds were used for 14 percent of the construction costs. About 15 percent of the costs were secured from debt financing, of which $317 million was acquired through the issue of tax-exempt bonds, and $3 million came from other forms of debt financing (e.g., loans). The Federal Government provided 7 percent (about $148 million) of the funds for new construction of research facilities.[13] This finding is consistent with the NSF's 1986 research facilities study in which Federal support for new construction was expected to be about 6 percent during the period from 1987-1991.

Figure 7
Sources of funds for construction of science/engineering research facilities: 1986 and 1987



Note: Percents may not sum to 100 because of rounding
Reference: Appendix table 4-1
Source: National Science Foundation, SRS

Public institutions secured a higher proportion of funds from State/local governments, and private institutions

[12] This report includes data on the direct costs of construction and repair/renovation and the sources of funds for these direct costs. No attempt was made to quantify the future indirect cost pressures resulting from current or planned projects reported in this survey.

[13] This figure refers to direct funding of facilities projects through grants or direct appropriations. Indirect costs recovered by an institution are usually considered institutional funds, and represent a portion of the institutional funds used for facilities construction and repair/renovation.

Table 15. Amount of funding for construction and repair/renovation projects on science/engineering research facilities started in 1986 and 1987, by institutional control

Sources	Construction			Repair/renovation		
	Total	Public	Private	Total	Public	Private
	(dollars in millions)					
Total	$2,062.8	$1,364.2	$698.7	$862.9	$438.8	$424.1
Federal Government	147.7	41.0	106.7	27.6	13.2	14.4
State/local government	782.9	757.8	25.1	234.6	227.9	6.7
Private	487.4	259.9	227.6	105.9	15.0	90.9
Institutional funds	291.3	110.1	181.2	330.5	156.3	174.2
Debt financing						
Tax-exempt bonds	317.3	192.8	124.5	152.6	25.8	126.8
Other debt	3.2	2.4	0.7	4.1	0.3	3.7
Other sources	33.1	0.2	33.0	7.7	0.2	7.5

Note: Details may not sum exactly to totals because of rounding.

Reference: Appendix Tables 4-2 and 4-4.

Source: National Science Foundation, SRS.

obtained a higher proportion of funds from private sources, similar to the findings of the 1986 NSF survey of academic research facilities. Public institutions expended $758 million in State/local government funds for new construction projects in 1986 and 1987. This represented a 97 percent share of the total $783 million in State/local funds for new construction, and these funds accounted for 56 percent of construction costs at public universities and colleges.

Private schools received slightly less than one-half of the private funds for facilities construction ($228 million out of $487 million) in 1986 and 1987, representing 33 percent of their new construction costs. Institutional funds represented a larger proportion of the construction costs at private schools (26 percent versus 8 percent).

Federal sources represented a larger share of the construction funds at private institutions (15 percent compared to 3 percent for public institutions), and the dollar value was larger as well -- $107 million compared to $41 million in Federal funds at public universities and colleges. While private institutions reported a proportionally similar reliance on tax-exempt bonds for new construction compared to public institutions (17 percent and 14 percent, respectively), the dollar amount was considerably higher at public institutions ($193 million compared to $125 million) because of public schools' higher level of construction activity.

Top 50 R&D institutions and those below the top 50 received similar amounts of Federal funds (about $74 million for each group), and these funds represented similar proportions of their total costs (6 percent and 8 percent, respectively). Top 50 institutions incurred more debt from tax-exempt bonds ($189 million versus $128 million), and used less other debt financing ($1 million versus $2 million) compared to other institutions, although the proportions represented by the bonds were similar, 16 percent and 15 percent, respectively (Appendix tables 4-1 and 4-2). The top 50 schools were similar to doctorate-granting institutions below the top 50 in the proportion of construction funds received from the various sources (table 16).

Site visits conducted for this study included a great deal of discussion about the funding of facilities projects. Some institutions indicated that the funding mix may change over time, particularly for new construction projects, even after the completion of a new building. For example, the original proposed sources of support for a project may not include tax-exempt bonds. Should the bond market become

Table 16. Sources of funds for construction and repair/renovation of research facilities among doctorate-granting institutions: 1986 and 1987

Funding sources	Construction		Repair/renovation	
	Top 50 in R&D	Below top 50	Top 50 in R&D	Below top 50
Federal Government	6%	8%	3%	3%
State/local government	35	39	11	41
Private	26	22	18	7
Institutional funds	14	17	38	42
Debt financing				
Tax-exempt bonds	16	13	28	7
Other debt	<1	<1	1	<1
Other sources	3	<1	2	<1

Note: Percents may not sum to 100 because of rounding.

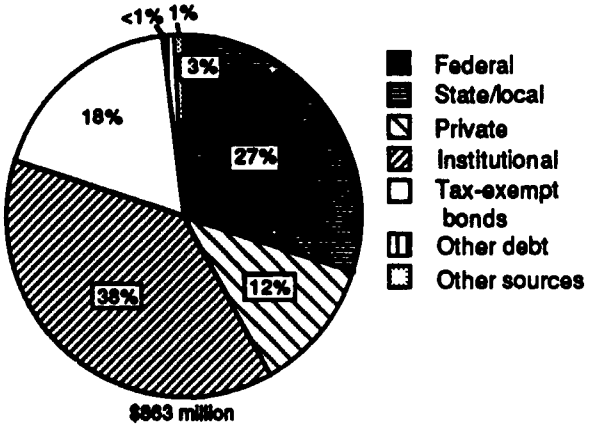
Source: National Science Foundation, SRS.

favorable during or after construction, however, the cost of the building may be partially refinanced through the issue of bonds. Alternatively, should the institution receive a gift, this money could be used to retire all or part of the debt resulting from a construction project. While institutions were asked to report the planned sources for the permanent financing[14] of the projects, it should be recognized that existing financial management practices do sometimes result in the adjustment of the funding mix.

Repair/Renovation: 1986 and 1987

Expenditures for the repair/renovation of research facilities totalled $863 million in 1986 and 1987. The largest source was institutional funds (38 percent), followed by State/local governments (27 percent) (figure 8). The Federal Government funded 3 percent of the costs of repair/renovation, about $28 million; this is somewhat lower than the 6 percent to 8 percent share of similar projects anticipated by respondents to NSF's 1986 survey on research facilities. Eighteen percent of the funds ($153 million) came from tax-exempt bond issues, and $4 million came from other debt, resulting in an estimated debt for the institutions of $157 million for the reported projects (table 15).

Figure 8
Sources of funds for repair/renovation of science/engineering research facilities: 1986 and 1987



Note: Percents may not sum to 100 because of rounding
Reference: Appendix table 4-3
Source: National Science Foundation, SRS

[14] Permanent financing refers to the planned means of financing the cost of a building over time. This excludes short-term arrangements (e.g., a 3-year construction loan) which allow the building process to go forward but are replaced by a more permanent funding mix within a relatively short period of time.

Public institutions obtained 52 percent of funds from State/local governments ($228 million), while private institutions obtained 41 percent of their funds ($91 million) from private sources. Private institutions also secured a far greater proportion (30 percent) from tax-exempt bonds than did public schools (6 percent). Of the total $157 million in debt financing for repair/renovation in 1986 and 1987, $130 million was incurred by private institutions.

Top 50 institutions differed from other doctorate-granting institutions in the funding mix for repair and renovation in 1986 and 1987 (table 16). While doctorate-granting schools below the top 50 received a much larger proportion of repair/renovation funds from State/local governments (41 percent compared to 11 percent), the top 50 schools relied more on private sources (18 percent compared to 7 percent), and financed a greater portion of the costs through tax-exempt bonds (28 percent versus 7 percent).

Sources of Funds for Planned Research Facilities Projects

New Construction: 1988 and 1989

The distribution of funding sources for planned new construction is similar to that observed for 1986 and 1987 projects. The Federal Government is expected to provide $222 million, representing 7 percent of new construction costs for these research facilities (figure 9 and table 17). As noted earlier, this proportion is similar to the level of Federal support projected for the period 1987-1991 in the 1986 NSF survey on research facilities at doctorate-granting institutions (6 percent). The largest single source is State/local government funding (34 percent or $1.2 billion), followed by private sources (23 percent or $774 million). Tax-exempt bonds are expected to provide funds to finance 19 percent of the total costs, and 5 percent will be financed with other debt. The resulting institutional debt is expected to be approximately $825 million for planned construction projects in the 2-year period.

The differences in funding mix between public and private institutions noted in previous discussions are also observed for planned sources of funding for new construction. That is, State/local government funds are expected to be the major source of support for public institutions (52 percent or $1.1 billion), and private institutions will rely more on private funds (44 percent or $563 million). While private institutions will rely on tax-exempt bonds for a greater proportion of their construction funds (27 percent

Table 17. Amount of funding for construction and repair/renovation projects on science/engineering research facilities planned for 1988 and 1989, by institutional control

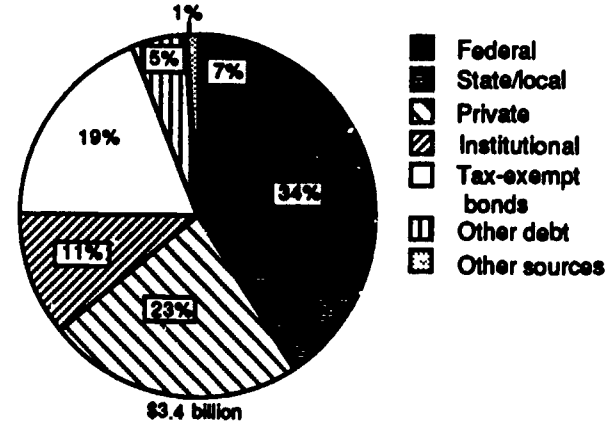
Sources	Construction			Repair/renovation		
	Total	Public	Private	Total	Public	Private
	(dollars in millions)					
Total	$3,398.7	$2,166.5	$1,282.2	$777.0	$444.5	$332.5
Federal Government	222.2	190.2	32.0	40.8	10.5	30.3
State/local government	1,152.2	1,105.4	46.8	245.9	239.9	6.1
Private	774.4	211.1	563.4	69.4	6.6	62.8
Institutional funds	389.9	248.5	141.4	301.0	150.8	150.2
Debt financing						
Tax-exempt bonds	662.4	322.5	339.9	86.2	22.2	64.0
Other debt	163.0	14.8	148.2	17.8	13.3	4.3
Other sources	34.5	24.0	10.5	16.0	1.3	14.8

Note: Details may not sum to totals because of rounding.

Reference: Appendix tables 4-6 and 4-8.

Source: National Science Foundation, SRS.

Figure 9
Sources of funds for construction of science/engineering research facilities: 1988 and 1989



Note: Percents may not sum to 100 because of rounding
Reference: Appendix table 4-5
Source: National Science Foundation, SRS

compared to 15 percent), the dollar amounts for public and private institutions are fairly similar ($340 million at private institutions and $323 at public institutions). The 27 percent of construction costs to be financed with tax-exempt bonds at private institutions, however, represents a substantial increase over the 17 percent reported for projects started in 1986 and 1987.

The planned sources of funding for top 50 schools are somewhat different from other doctorate-granting institutions (table 18). While top 50 institutions will rely somewhat more on private sources and tax-exempt bonds, doctorate-granting schools below the top 50 will receive a larger share of their funds from State/local governments, and more from Federal sources (11 percent versus 3 percent). Similar differences were found between top 50 schools and all institutions below the top 50 (Appendix tables 4-5 and 4-6).

Repair/Renovation: 1988 and 1989

The distribution of funding sources for 1988 and 1989 repair/renovation is similar to that reported for 1986 and 1987 (figure 10 and table 17). The major sources of funds for planned repair/renovation of research facilities are institutional funds (39 percent) and State/local government funds (32 percent). Federal sources are expected to provide 5 percent of the costs (about $41 million). A

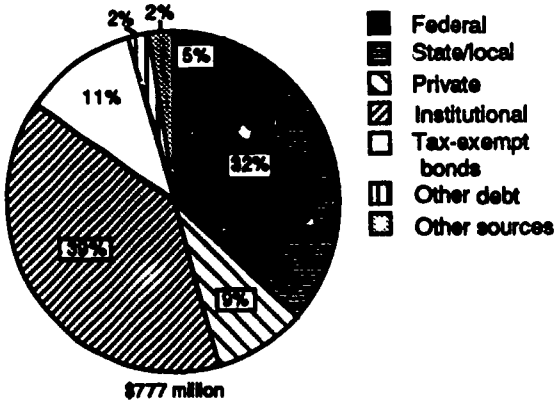
Table 18. Sources of funds for construction and repair/renovation of research facilities among doctorate-granting institutions: 1988 and 1989

Funding sources	Construction		Repair/renovation	
	Top 50 in R&D	Below top 50	Top 50 in R&D	Below top 50
Federal Government	3%	11%	6%	4%
State/local government	29	36	20	43
Private	26	20	13	3
Institutional funds	11	12	39	41
Debt financing				
Tax-exempt bonds	24	15	14	8
Other debt	8	4	4	<1
Other sources	0	2	3	1

Note: Percents may not sum to 100 because of rounding.

Source: National Science Foundation, SRS.

Figure 10
Sources of funds for repair/renovation of science/engineering research facilities: 1988 and 1989



Note: Percents may not sum to 100 because of rounding
Reference: Appendix table 4-7
Source: National Science Foundation, SRS

relatively small proportion is expected to come from private support (9 percent). Tax-exempt bonds will be used to finance 11 percent of the repair/renovation costs ($86 million), and other debt (e.g., loans) will be used to finance 2 percent ($18 million), resulting in institutional debt of about $104 million for the 2-year period.

As was observed in the previous sections, public and private institutions differ in the expect sources of funds for repair/renovation, with public universities anticipating more State/local government support (54 percent compared to 2 percent). Private institutions expect more from private sources (19 percent compared to 1 percent) and tax-exempt bonds (19 percent compared to 5 percent). The proportion to be financed by bonds at private institutions, however, is substantially lower than the 30 percent reported for projects started in 1986 and 1987. Private institutions will rely more on institutional funds than public universities and colleges for repair/renovation costs (45 percent versus 34 percent).

As described in previous sections, top 50 institutions differ from other doctorate-granting institutions (table 18). The top 50 schools plan to secure more funds from private sources than others (13 percent versus 3 percent). They also will finance a somewhat larger portion of their costs through tax-exempt bonds (14 percent versus 8 percent), resulting in a larger debt ($63 million) for top 50 schools. Doctorate-granting schools below the top 50 will receive a larger share of funds from State/local governments (43 percent compared to 20 percent). Similar differences were found between top 50 schools and all institutions below the top 50 (Appendix tables 4-7 and 4-8).

Combining the data reported in previous sections, the total institutional debt incurred from projects reported in this survey is approximately $1.4 billion, if all projects are completed and funded as anticipated. About $812 million of this debt has been, or will be, incurred at private institutions; about $953 million has been, or will be, incurred by top 50 research universities.

Private Institutions and the Limit on Tax-exempt Bonds

Tax-exempt bonds are a major source of funding for capital projects at private universities and colleges. They were used to fund 17 percent of construction costs at private institutions (about $125 million) in 1986 and 1987, and are expected to finance 27 percent of construction costs (about $340 million) in 1988 and 1989. In addition, tax-exempt bonds were used to finance 30 percent ($127 million) of repair/renovation costs in 1986 and 1987, and will fund 19 percent ($64 million) in 1988 and 1989, according to institutional plans. The use of bonds by private institutions, then, will increase by about 60 percent, from $252 million in 1986 and 1987 to $404 million in 1988 and 1989, if planned projects are completed and funded as anticipated. These projects represent a total dollar value of tax-exempt bonds of about $656 million at private institutions for the projects reported in this survey.

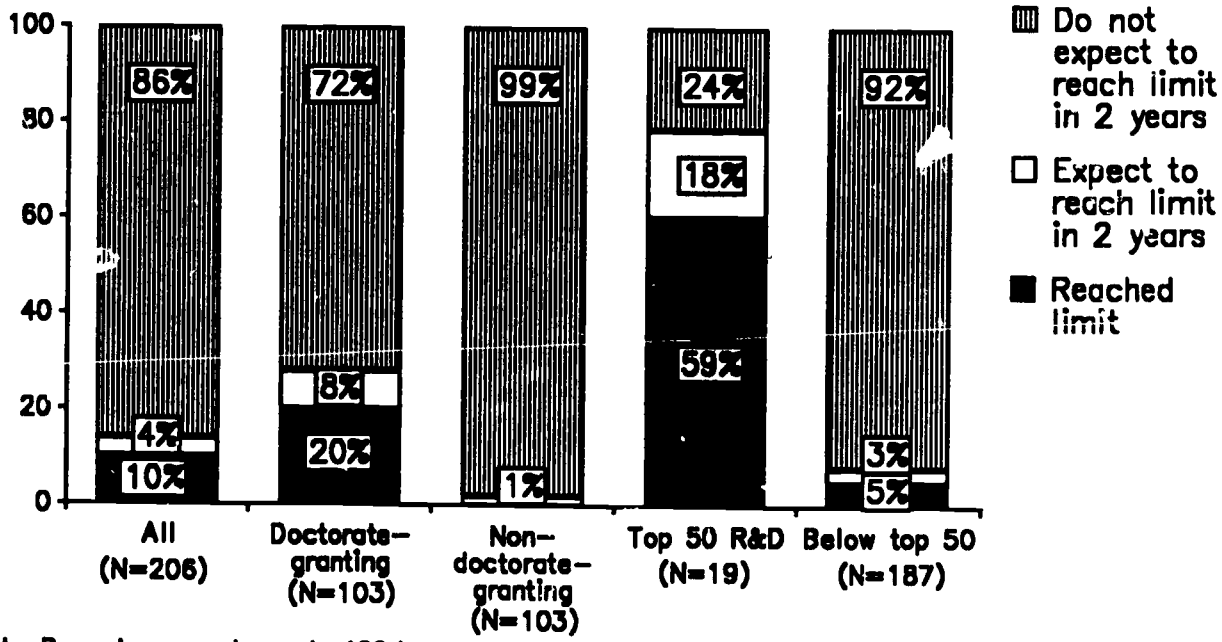
Recent tax reform legislation placed a per-institution limit on outstanding tax-exempt bonds of $150 million for private universities and colleges. At the time this survey was conducted, 10 percent of private, research-performing institutions had reached the $150 million cap, and another 4 percent expect to do so within the next 2 years (figure 11). All of those which have reached the cap are doctorate-granting universities. Twenty percent of the private doctorate-granting universities have reached the limit and an additional 8 percent anticipate doing so in the next 2 years.

The proportion which have already reached the limit on bonds is much higher among the 19 private universities that are in the top 50 in R&D; 11 schools have reached the cap and another 3 anticipate doing so in the next 2 years.

The status of medical schools relative to the cap on tax-exempt bonds is somewhat worse than at the institutions as a whole, since they are all located at doctorate-granting institutions, and several are at top 50 schools. Twenty-seven percent of medical schools are located at institutions which

have reached the $150 million limit, and an additional 10 percent are located at institutions that anticipate reaching the cap within the next 2 years (Appendix table 4-10). Eleven of the 15 private medical schools at top 50 R&D institutions reported that their institutions have reached the limit on these bonds, and 2 more anticipate doing so in the next 2 years.

Figure 11
Status of private institutions relative to $150 million limit on tax-exempt bonds: 1988



Note: Percents may not sum to 100 because of rounding.
Reference: Appendix table 4-9
Source: National Science Foundation, SRS

5. CONDITION AND ADEQUACY OF RESEARCH FACILITIES

HIGHLIGHTS

- The condition of research facilities at universities and colleges is varied. Twenty-four percent of the science and engineering research space is suitable for use in the most scientifically sophisticated research in its field. Another 37 percent is effective for most purposes. However, 39 percent is in need of limited (23 percent) or major (16 percent) repair or renovation to be used effectively.

- Regarding the amount of research space, the modal response for most disciplines was "generally adequate." The amount of space was most often rated as "adequate" in mathematics (21 percent), and most often rated "inadequate" in engineering and biological sciences in medical schools (51 percent each).

- Infrastructure support was most frequently rated as "generally adequate." The aspect most likely to be rated "adequate" in a majority of disciplines was power systems (24 percent to 36 percent in most fields). Least likely to be rated "adequate" were air decontamination (11 percent to 18 percent in most fields) and data communications (12 percent to 19 percent in most fields).

- A comparison between needed and planned repair/renovation indicates that universities and colleges are deferring $3.60 in needed work for every $1.00 of repair/renovation. The ratio of deferred new construction to planned new construction is about $2.50 to $1.00.

This chapter discusses the survey's findings concerning the physical condition of research facilities in the sciences and engineering (S/E) and the functional adequacy of selected aspects of the facilities.[15] Discussions with the institutions indicated that, for the most part, deans and department chairs reported on the condition and adequacy of facilities. However, a small number of institutions indicated that they have detailed condition information on a central data base, and that the facilities office was able to respond to these items on the basis of those data.

The first section of this chapter provides an overview of the condition of facilities, followed by a discussion of differences between S/E disciplines and institutional types. The adequacy of the amount of research space available to the institutions is presented next. Data are then analyzed on the adequacy of selected aspects of facilities. Consistent themes that emerged in responses to the open-ended survey item on facilities needs and information obtained during site visits at 30 institutions are included to illuminate the findings.[16]

Condition of Research Facilities

Institutions were asked to report the proportion of their science and engineering research space that falls into each of the following four categories:

A - Suitable for the most highly developed and scientifically sophisticated research in the discipline;

B - Effective for most purposes, but not applicable to category A;

C - Effective for some purposes but in need of limited repair or renovation; and

D - Requiring major repair or renovation to be used effectively.

By summing and weighting the amount of space in each discipline which is reported for each of these four categories, the proportion of the total research space nationally that is in each of these statuses is derived. Twenty-four percent of the S/E space is suitable for use in the most highly developed and scientifically sophisticated research in its field. Another 37 percent of the space is suitable for most research purposes, but not for the most highly developed and scientifically sophisticated research. Thirty-nine percent of the space is in need of some repair or renovation to be used effectively; 23 percent requires limited repair or renovation, and 16 percent requires major repair or renovation (Appendix table 5-1).

Individuals may differ in their opinions about the amount of space that should be suitable for the most scientifically sophisticated research. It does not seem cost-effective that all research facilities should be applicable to this category.

[15] The definitions of condition and adequacy are provided in the text of this chapter (condition on this page, and adequacy on page 28), and in the questionnaire (Appendix D).

[16] Not all institutions provided a narrative description in response to the open-ended item on the survey. Among those who did respond to the item, the answers varied considerably in length and content. This report discusses the common themes found in the responses.

Not all research is the most scientifically sophisticated in its field, nor requires such facilities. However, most would agree that it is undesirable to have a substantial proportion of the available space in need of repair or renovation to be used effectively.

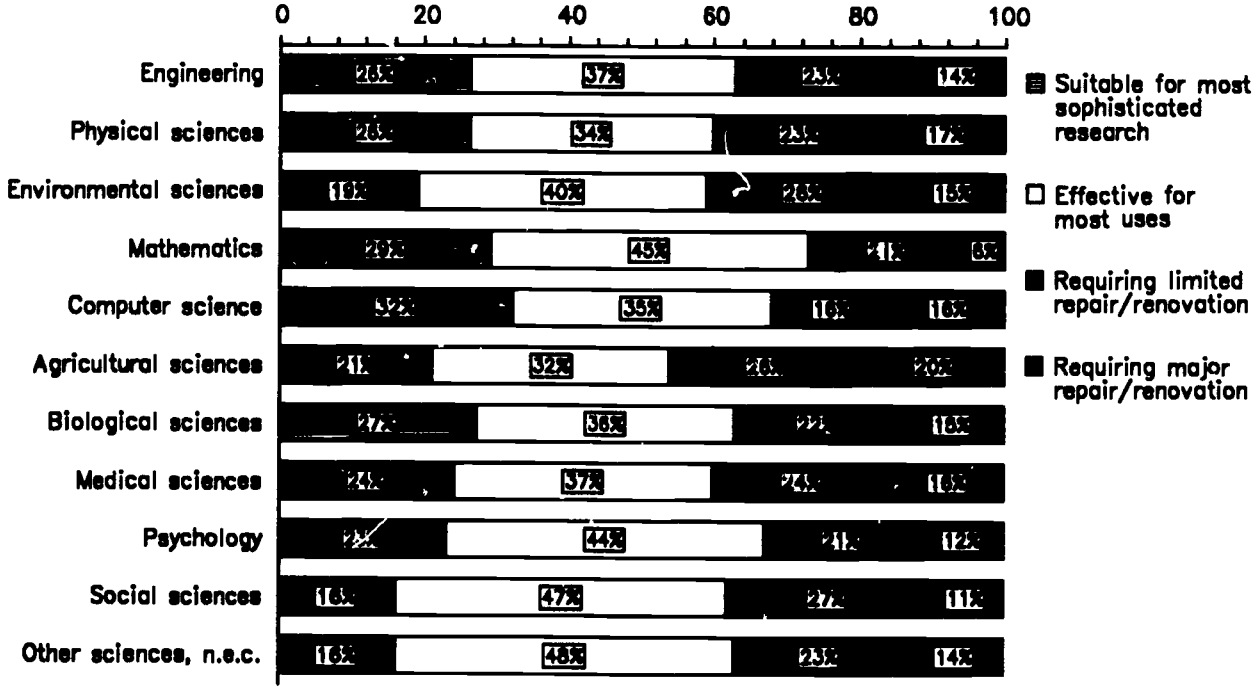
Specific Science and Engineering Disciplines

With few exceptions, the various S/E disciplines are relatively similar in terms of the condition of their facilities (figure 12). While roughly 60 percent to 70 percent of the space in most disciplines was rated either as being suitable for the most highly developed and scientifically sophisticated research in its field or effective for most purposes, from about 30 percent to 40 percent in most fields was rated as being in need of either limited or major repair or renovation to be used effectively. Specifically, from 16 percent to 32 percent of the research space in S/E disciplines was reported as suitable for the most highly developed and scientifically sophisticated research in the discipline. Another 32 percent to 48 percent was designated as being effective for most purposes, although not for the most highly developed and scientifically sophisticated research. A range of 16 percent to 27 percent of the research space was reported to be in need of limited repair or renovation for effective use, and, with the exception of mathematics, 11 percent to 20 percent required major repair or renovation to be used effectively.

The discipline with the the greatest proportion of space in need of repair or renovation to be used effectively was agricultural sciences, with 20 percent needing limited repair or renovation and 26 percent needing major repair or renovation. Forty-one percent of the space in environmental sciences was reported to be in need of repair or renovation to be used effectively, but little renovation activity was reported for this field -- this is consistent with the findings of NSF's 1986 facilities survey.

In only one field, mathematics, was less than one third of the space reported as needing repair or renovation to be used effectively. Mathematics (74 percent) had the most space rated as either suitable for the most highly developed and scientifically sophisticated research or effective for most purposes; as noted in Chapter 3, almost no facilities work is planned in this field. In all other fields except agricultural

Figure 12
The condition of science/engineering research space, by discipline: 1988



Note: Percents may not sum to 100 because of rounding.
Reference: Appendix table 8-1
Source: National Science Foundation, SRS

sciences, from 59 to 67 percent of the space was rated in one of these two categories.

In engineering, 26 percent of the research space was rated as suitable for the most highly developed and scientifically sophisticated research, and 37 percent was rated as effective for most purposes. Thirty-seven percent of the space in engineering was reported as requiring repair or renovation -- 23 percent limited, and 14 percent major repair or renovation. Similar proportions for each category were reported for physical and medical sciences.

Differences by Type of Institution

Academic officials at doctorate-granting institutions reported more of their research space as being suitable for the most scientifically sophisticated research (24 percent) than did those at non-doctorate-granting institutions (15 percent). The reverse is true for the proportion of space rated as effective for most purposes; non-doctorate-granting institutions reported a higher share of their space in this category than did doctorate-granting universities. The two groups, however, were similar in the proportion of space rated as needing limited or major repair or renovation (table 19). Public and private institutions reported similar shares of space in all categories, as did the top 50 R&D schools and those ranked below the top 50 (Appendix tables 5-2 through 5-5).

Table 19. The condition of academic research space: 1988

Condition	Highest degree granted	
	Doctorate-granting	Non-doctorate-granting
	(percent of research space)	
Suitable for most highly developed and scientifically sophisticated research	24%	15%
Effective for most purposes	36	50
Requiring limited repair or renovation	23	24
Requiring major repair or renovation	16	11

Note: Percents may not sum to 100 because of rounding.

Reference: Appendix tables 5-2 through 5-5.

Source: National Science Foundation, SRS.

In specific S/E fields, academic officials at doctorate-granting universities rated a higher proportion of space in most fields as suitable for the **most highly developed and scientifically sophisticated research** in its field than those at non-doctorate-granting schools (Appendix table 5-2). The exceptions are agricultural sciences and "other sciences," in which more of the space was rated in this category by non-doctorate-granting schools.

At public institutions, a greater proportion of computer science facilities were rated as suitable for the most highly developed and scientifically sophisticated research than at private colleges and universities. However, at private institutions, more of the facilities in physical, environmental, agricultural, and "other" sciences were rated in this category. Other fields were roughly similar at public and private institutions.

A greater proportion of agricultural sciences facilities at the top 50 institutions were rated as suitable for the most scientifically sophisticated research, but in most other fields the shares of space rated in this category were similar to other institutions. Schools below the top 50 rated more space in this category than did the top 50 schools in only three disciplines, engineering, environmental sciences, and computer science.

Doctorate-granting universities reported greater proportions of physical and agricultural sciences space **in need of major repair or renovation** to be used effectively; non-doctorate-granting institutions reported a greater proportion of "other sciences" space in this category (Appendix table 5-5). Public institutions reported a greater proportion of environmental sciences and medical sciences space in medical schools as requiring major repair or renovation, while private institutions reported a higher proportion of computer science space in this category. The top 50 institutions indicated a greater proportion of space in physical, computer, and medical sciences and psychology as requiring major repair renovation than did those below the top 50.

While the need for normal maintenance and repair of facilities is expected, many institutions indicated that they have backlogs of deferred repair and renovation; this was frequently mentioned during site visits, and was one of the most commonly discussed themes in the open-ended responses to the survey. Doctorate-granting institutions were more likely than others to comment that they had difficulty in obtaining funds for needed repair and renovation, resulting in backlogs of projects. The amounts

of the backlogs vary from institution to institution, and many do not keep ongoing records of maintenance or repair projects that have been deferred. Some institutions reported during site visits, however, that their total (research and nonresearch) deferred maintenance backlogs add up to millions of dollars of necessary repairs and renovations. This finding is consistent with the report of a recent survey conducted by the Society for College and University Planners. The results of their survey indicate that, while almost all of the surveyed institutions planned rehabilitation and/or new construction within the following 5-year period, the projects would only cover deferred maintenance and the institutions' current educational programs. Adequate funding was considered to be a major challenge by the respondents, especially for rehabilitation.[17]

The responses to the open-ended item on the survey provide some insight into factors affecting the condition of research facilities. The aging of buildings and the need for suitable facilities to support research appear to be very important factors. These were mentioned by a large number of institutions, usually in the context of deferred maintenance. Typical of the comments on this topic are:

- *The age and size of our physical plant, coupled with rapid changes in science and technology, will require continuing replacement and upgrading of our research facilities (across disciplines) over time. (Private, doctorate-granting university)*

- *Remodeling of obsolete facilities...has been the highest campus capital budget priority for more than 12 years, bu state capital funding priorities...have consistently evaded this need. (Public, doctorate-granting university)*

- *Our objectives are to fully modernize our oldest research buildings, which are now 15-20 years old. (Private, doctorate-granting university)*

- *Along with other research universities [we] must cope with the rapid rate of obsolescence of our research facilities as the requirements for sophisticated environments continue to drive our renovation program. (Private, doctorate-granting university)*

Health and safety concerns, and the need to comply with Federal and State regulations, are also of concern to a large number of institutions. This concern was frequently mentioned during the study's site visits and was also discussed in several survey responses. Federal regulations were most often mentioned in connection with animal quarters, and some institutions cited the high cost of constructing such facilities. Some examples of institutional comments are:

- *The implementation of new experimental equipment and procedures demands the added expense of ensuring a high level of safety. The safety hazards found in older facilities require extensive funding in order to maintain high safety standards. (Public, doctorate-granting university)*

- *...inadequate, unsafe, and inappropriately located research spaces within patient care areas is one of the most serious problems facing [university medical center].... Deficient space is compromising the safe and efficient conduct of presently funded research projects as well as seriously hindering the recruitment of needed research and teaching faculty. (Public, doctorate-granting university medical center)*

- *I suppose the most intractable problem is space for animal research. We have a long and tortured history with the problem which I will not belabor. Let me just say that changing Federal regulations, competition for virtually nonexistent space, and an apparently low priority for behavioral laboratories... make solutions very difficult even without the basic cost issues. (Private, doctorate-granting institution)*

Adequacy of the Current Amount of Research Space

Institutions were asked to rate the adequacy of several aspects of their research facilities, including the amount of research space, according to the following scale:

1 - Adequate -- sufficient to support all the needs of your research in the discipline;

2 - Generally adequate -- sufficient to support most research needs in the discipline, but may have some limitations;

3 - Inadequate -- not sufficient to support the needs of your research in the discipline;

4 - Non-existent, but needed; or

5 - Inapplicable, or not needed.

[17] The State of College and University Facilities. Society for College and University Planning and David Helpern, PC, 1987.

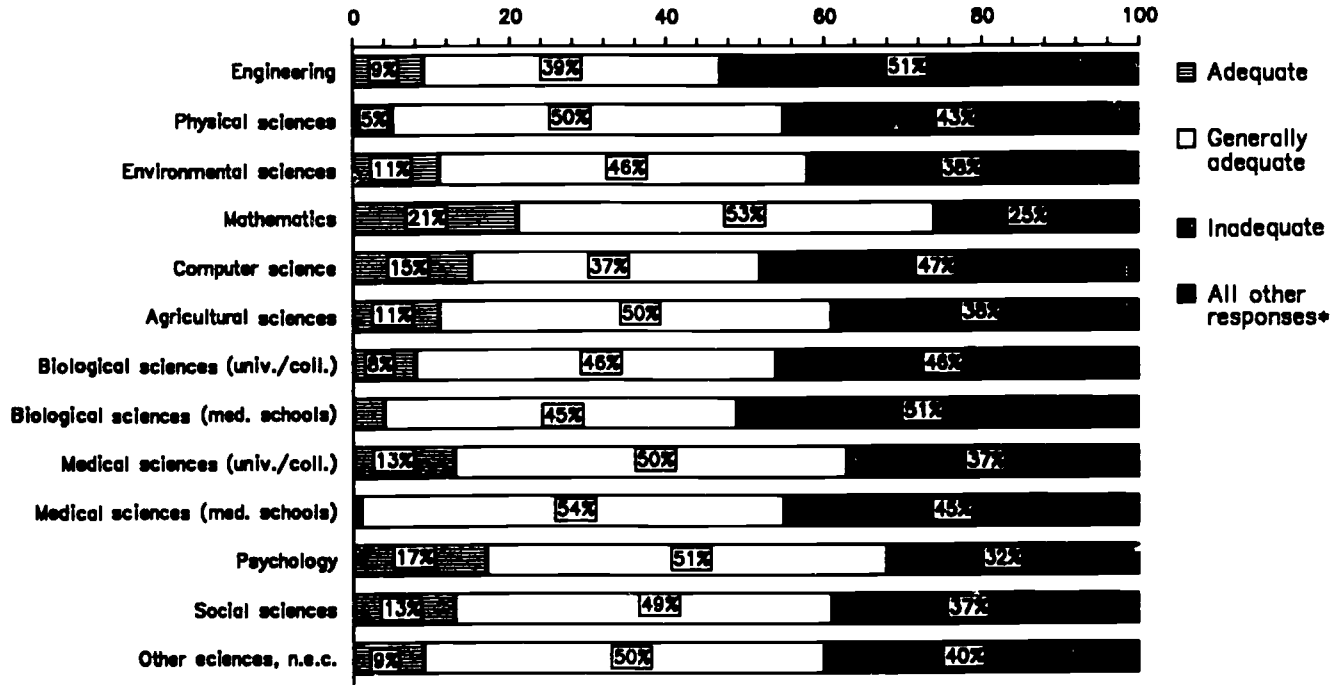
The amount of research space was reported as "adequate" to support the needs of S/E research programs at only 1 percent to 21 percent of institutions, depending on the discipline (figure 13). Mathematics space was most often rated as "adequate" (21 percent), and medical sciences in medical schools (1 percent) and biological sciences in medical schools (4 percent) were rated "adequate" by the lowest proportion of respondents. From 37 percent to 54 percent of institutions reported that the amount of research space was "generally adequate," the modal response for most disciplines. From 25 percent to 51 percent reported that the amount of space in S/E disciplines was "inadequate" to support the needs of the research program. Those disciplines in which the amount of space was most often rated as "inadequate" were engineering, physical sciences, computer science, biological sciences (both in universities and colleges and in medical schools), and medical sciences in medical schools, ranging from 43 percent to 51 percent each.

Doctorate-granting institutions, which house nearly all of the S/E research space, were more likely to rate the amount of space in many fields as "inadequate" than were non-doctorate-granting institutions. Similarly, top 50 institutions, which house as much research space as the 474 other institutions in the population, were more likely to rate the amount of space as "inadequate" in all fields. The differences between top 50 universities and others in the proportion rating the amount of space as "inadequate" were substantial in almost all disciplines (Appendix table 5-7).

The majority of research administrators and deans surveyed by NSF in 1986 reported that the amount of research space was "less than needed." The data from the current survey generally support that finding, although lower proportions reported the amount of space as "inadequate." It should be kept in mind, however, that, in addition to the proportion rating the amount of space as "inadequate," a considerable proportion of respondents to the current survey reported that the amount of space was "generally adequate," but with some limitations. Therefore, the figures in this survey represent a finer distinction, and are not directly comparable with the 1986 data.

One of the most common themes discussed in the open-ended responses to the survey was the need for additional

Figure 13
Adequacy of the amount of research space, by discipline: 1988



*Detail on other responses appears in the appendix tables.
Note: Because of space limitations, values of less than 5 percent are not shown.
Reference: Appendix table 5-6
Source: National Science Foundation, SRS

space and/or the crowding in research facilities. A recurring theme in the responses was that many institutions plan to expand their research programs; while this was mentioned most often by doctorate-granting institutions, a small number of non-doctorate-granting schools also expressed this goal. A comment often made, primarily by doctorate-granting universities, to support the need for additional space was that the institution's R&D expenditures had grown substantially in recent years without a parallel expansion in facilities. NSF's survey of R&D expenditures at colleges and universities indicates that separately budgeted research increased by 37 percent from 1983 to 1986, from $7.8 billion to $10.7 billion. Some institutions have experienced more growth, of course, and others less. Some examples of comments from responding institutions about this growth are:

- *Research funding at [university] has been growing about 10 percent per year beyond inflation.... Our current research has filled all available space and some disciplines are very crowded. (Public, doctorate-granting university)*

- *We are making inroads on the problem [facilities limitations]. However, the pace at which sponsored research is growing has a timeline which, even assuming no constraints on funding, outpaces the space available. (Private, doctorate-granting university)*

- *The research facilities...are not keeping pace with the expansion of research activities. While all space is at a premium, that allocated for research is lagging behind that being constructed for other academic activities. (Public, doctorate-granting university)*

- *While the dollar value for sponsored research projects has almost doubled over the past three years, the university's appropriation for such activities has remained constant.... There is a pressing need for both additional and renovated research space in all disciplines. (Private, non-doctorate-granting institution)*

In an effort to meet space needs, alternatives to new construction are utilized by many institutions. Conversion of space from nonresearch use to research use is not uncommon. For example, a new academic building may be constructed and some or all of the space in the older facility converted to research space. Institutions may also borrow space from one field to meet research needs in another, and may take needed space from existing programs to accommodate new or expanding programs.

The data reported in this survey demonstrate that not all universities and colleges, nor all disciplines, share this need for additional research space. Several of the non-doctorate-granting institutions, and a small number of doctorate-granting universities, indicated that their primary focus is on teaching, and that research is an ancillary activity that maintains the currency of faculty expertise and provides research experience to their students. The focus on organized research and facilities for this research are not high priorities at many of these institutions. An approximately equal number of non-doctorate-granting institutions, however, indicated that they do place a high priority on research, and plan to expand their research programs, as noted above. Among these non-doctorate-granting schools, research was generally discussed in the context of its relationship to instruction, and a small number of institutions noted that research experience supports the placement of their students into science and engineering graduate programs.

A small number of institutions indicated that the construction projects reported for 1988 and 1989, if funded and completed, will meet their anticipated facilities needs for the next few years. These institutions, however, were few in number compared to those that expressed a need for additional space.

Adequacy of Selected Aspects of Research Facilities

Infrastructure support, according to the institutions, is an essential part of the research facilities issue. While bricks and mortar are important in themselves, the infrastructure systems (utilities, data communication, and related support systems) are required so that the bricks and mortar can support the research enterprise.

Academic officials, primarily S/E deans, were asked to rate the adequacy of selected aspects of their research facilities, using the scale presented in the previous section. These systems represent problem areas identified by respondents during the pretest phase of the study:

- Data communication systems;
- Power systems;
- Heating, ventilation, and air conditioning (HVAC);
- Air decontamination (e.g., fume hoods); and
- Toxic waste disposal.

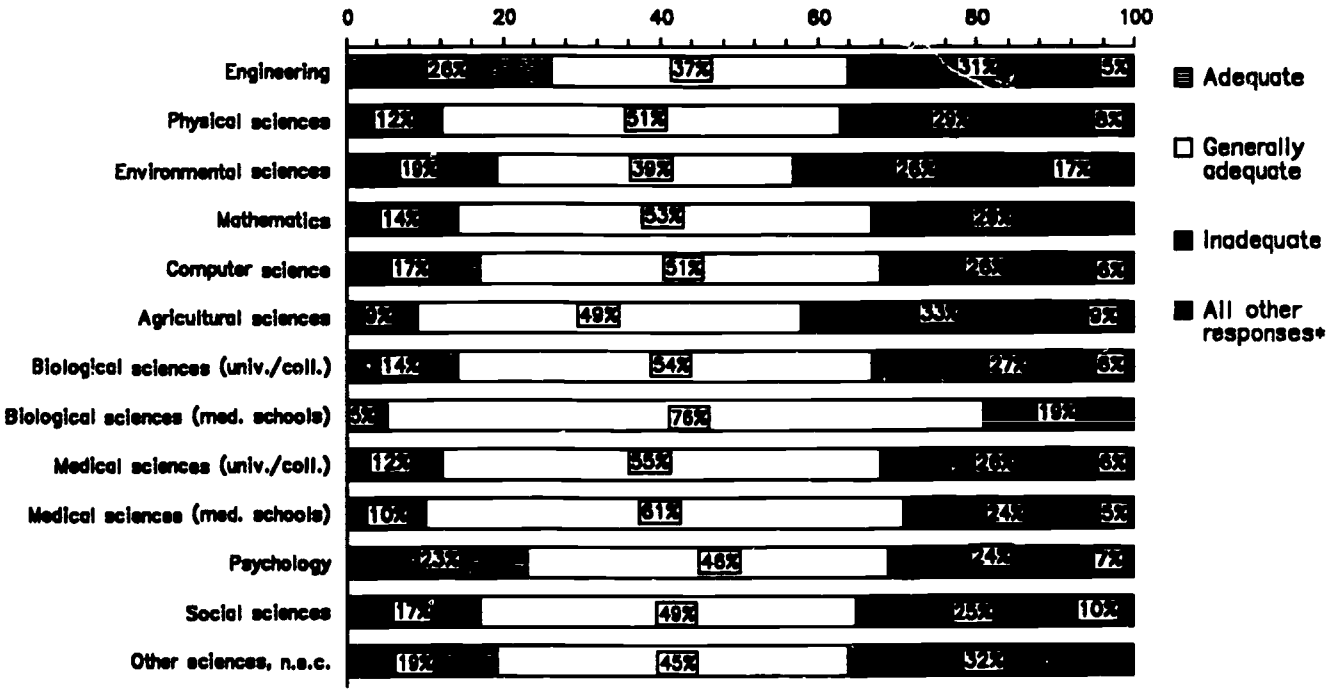
A small number of institutions reported difficulty in assigning only one rating to each of these aspects for each discipline. This difficulty seems to have occurred most often when a discipline was housed in multiple buildings with variations in their infrastructure support. While most respondents, during followup, were able to select the single rating that best represented their institutions, some reported that no one rating would truly reflect the status of their facilities. These cases were small in number, only one or two percent of responses in any given discipline, and are reported separately in the Appendix tables as "varied." For ease of presentation, these responses, along with categories 4 and 5 above, appear in graphics as "all other responses."

Data Communication Systems

Systems for data communication represent an area of infrastructure support in which technology is rapidly changing. A number of institutions have recently installed fiber optic networks for data communication, or are planning to do so. Such systems provide data links between campus offices and central mainframes, and provide access to bulletin boards and electronic mail networks. Comments from the institutions indicate that the demand for such services is growing, and that the cost of these systems requires a major investment.

Data communication systems were rated as "adequate" to support the research needs of 9 percent to 20 percent of institutions in most disciplines (figure 14). A lower proportion of institutions rated their data communiction systems as "adequate" in biological sciences in universiities and colleges, and a somewhat larger proportion did so in engineering and psychology. The modal response for all disciplines was "generally adequate" (from 37 percent in engineering to 76 percent in biological sciences in medical schools). The data communication systems are considered "inadequate" to support the research needs of 19 percent to 33 percent of institutions in S/E disciplines.

Figure 14
Adequacy of data communication systems, by discipline: 1988



*Detail on other responses appears in the appendix tables.
Note: Because of space limitations, values of less than 5 percent are not shown.
Reference: Appendix table 5–8
Source: National Science Foundation, SRS

Power Systems

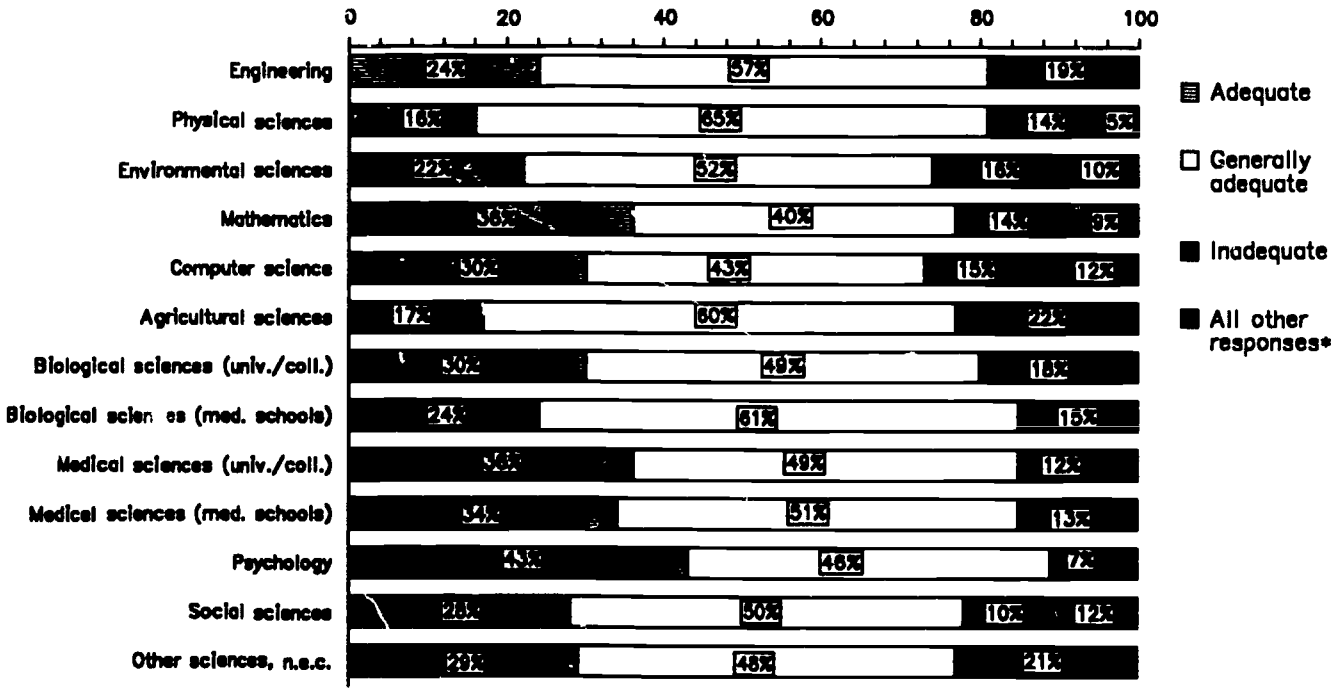
The growth of the research enterprise cited earlier in this report, the new technologies used in science and engineering research, and the proliferation of personal computers have significantly increased the power needs of the institutions. The need for air conditioning systems to cool buildings that contain large amounts of temperature-sensitive instrumentation has added to the burden on power systems. Several institutions indicated, during site visits, that the amount of available power was inadequate and that their needs included the rewiring of some buildings and expansion of their substations.

Sixteen percent to 43 percent of the institutions rated their power systems as "adequate" (figure 15); the highest proportion is found in psychology (43 percent) and the lowest in physical and agricultural sciences (16 percent and 17 percent, respectively). In other fields, 22 percent to 36 percent of academic officials reported that power systems were adequate. Again, the modal response was "generally adequate." From 7 percent to 22 percent of the institutions reported that their power systems were "inadequate" to support research in science and engineering disciplines. The field in which power systems were most often rated "inadequate" were agricultural and "other" sciences (22 percent and 21 percent, respectively); in most disciplines, from 12 percent to 19 percent rated power systems as inadequate.

Heating, Ventilation, and Air Conditioning (HVAC)

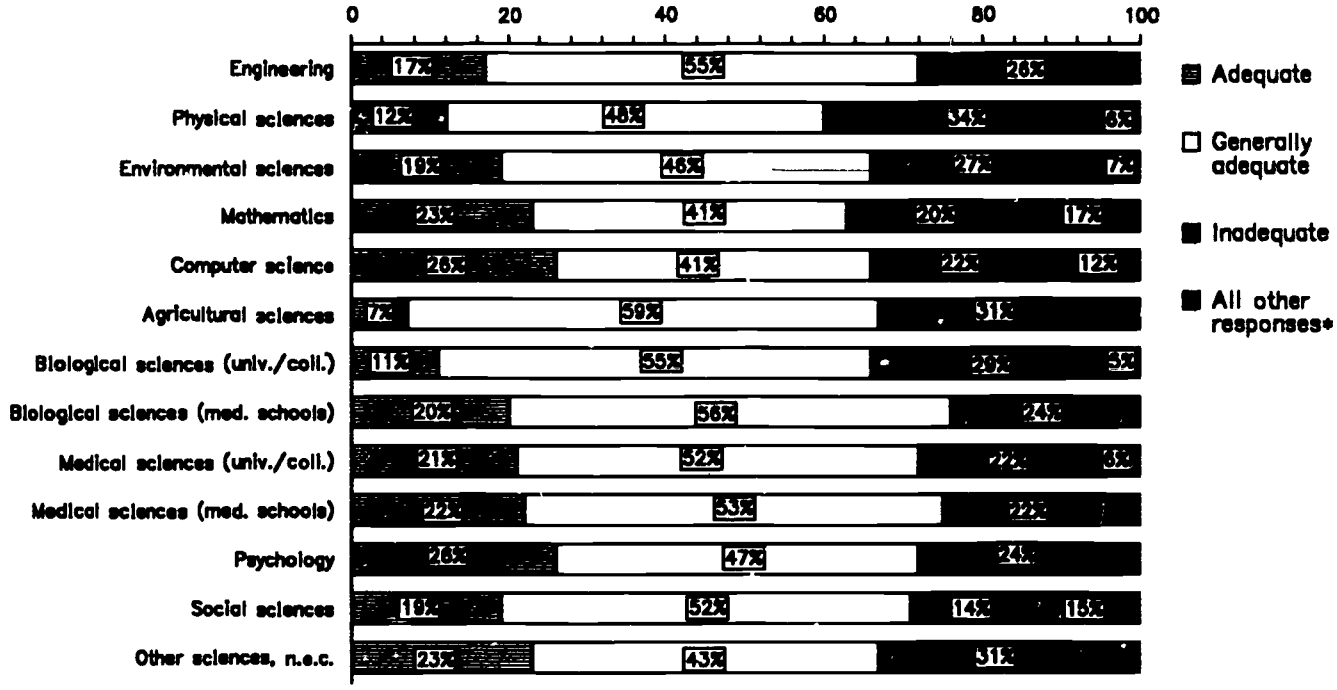
Air handling systems were considered an issue (most often in connection with cooling) by several institutions. One institution indicated that the campus had no air conditioning whatsoever, and that this was problematic for them, particularly in those facilities that housed many computers or other types of research instrumentation. A similar comment from another institution, in reference to a particular building, was cited in the 1986 research facilities report.

Figure 15
Adequacy of power systems, by discipline: 1988



*Detail on other responses appears in the appendix tables.
Note: Because of space limitations, values of less than 5 percent are not shown.
Reference: Appendix table 5-9
Source: National Science Foundation, SRS

Figure 16
Adequacy of heating, ventilation, and air conditioning (HVAC), by discipline: 1988



*Detail on other responses appears in the appendix tables.
Note: Because of space limitations, values of less than 5 percent are not shown.
Reference: Appendix table 5-10
Source: National Science Foundation, SRS

From 7 percent to 26 percent of institutions rated their HVAC systems as "adequate" (figure 16); HVAC systems in agricultural sciences and biological sciences in universities and colleges had the lowest proportion rated as adequate (7 percent and 11 percent, respectively). The modal response, as with other selected aspects of facilities, was "generally adequate." From 14 percent to 34 percent of the respondents reported that the HVAC systems at their institutions were "inadequate" for their research needs. Physical, agricultural, and "other" sciences were the fields in which HVAC was most often rated as "inadequate" (31 percent to 34 percent each).

Air Decontamination

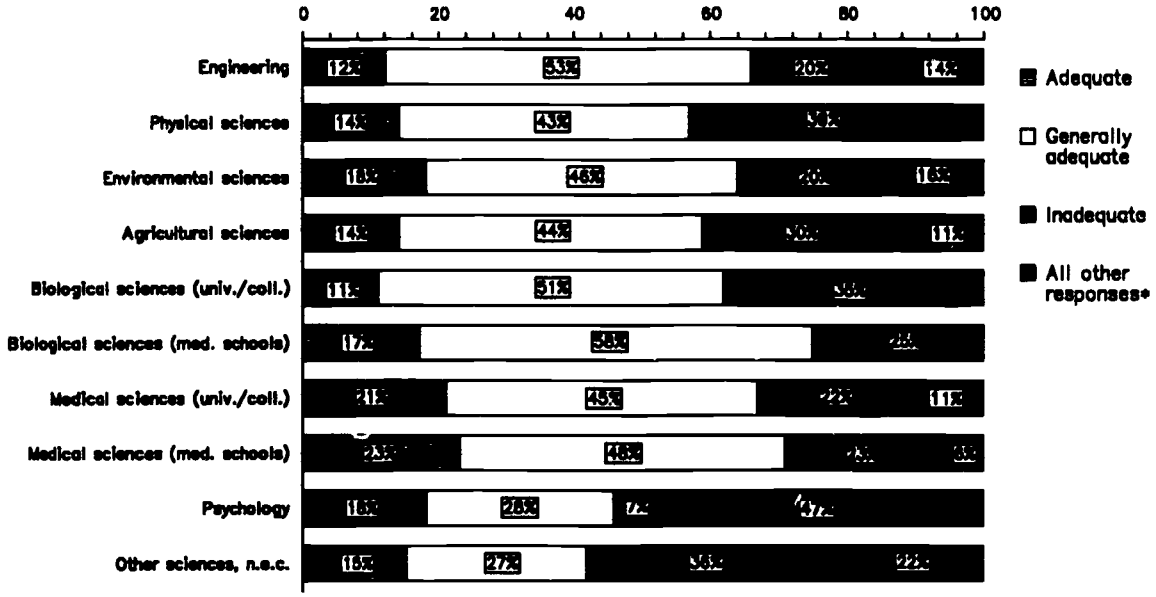
Air decontamination (e.g., fume hoods) is not needed in some science and engineering fields, nor do all institutions with research in a given field need air decontamination for their research. In those fields to which it is applicable, 11 percent to 23 percent of the institutions rated air decontamination as "adequate," depending on discipline (figure 17). Once again, the modal response was "generally adequate." In physical, agricultural, biological, and "other" sciences, air decontamination was rated "inadequate" by 30 percent to 39 percent of the respondents. In other fields, 20 percent to 25 percent rated air decontamination as "inadequate," with the exception of psychology (7 percent), in which 45 percent of institutions rated air decontamination as inapplicable to their research.

Toxic Waste Disposal

Many institutions have contracts with outside organizations for the disposal of toxic waste, but must have facilities in place for the handling of waste materials prior to pickup and disposal by the contractor. This is a major health and safety concern, and is also a politically sensitive issue for many institutions. Like air decontamination, however, toxic waste disposal is not needed in some disciplines.

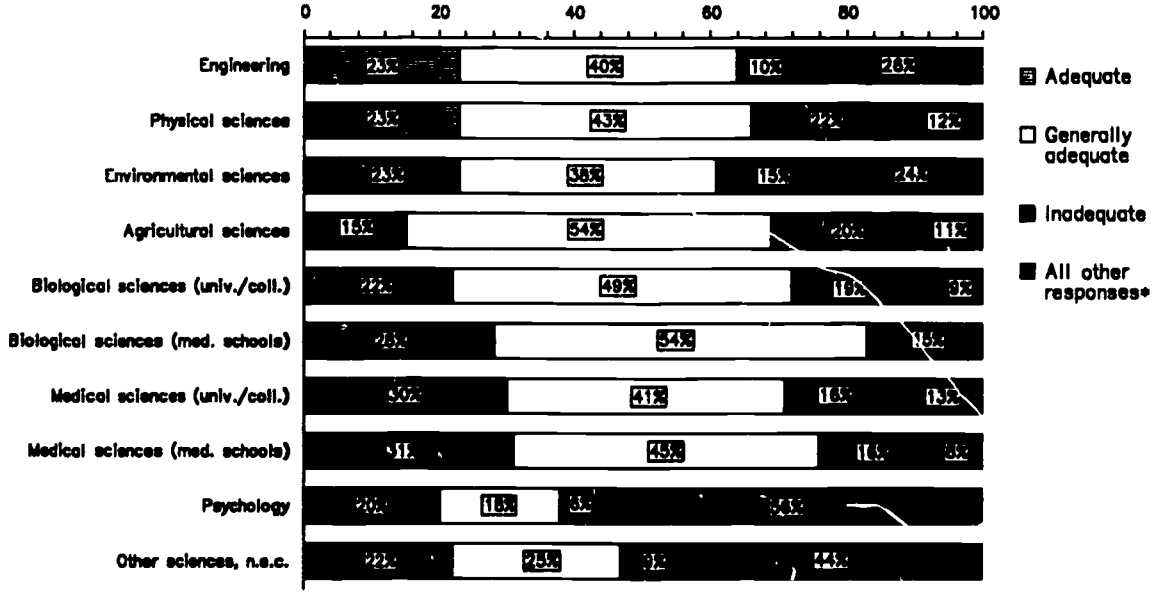
From 15 percent to 31 percent of academic officials rated toxic waste disposal facilities as adequate (figure 18). Medical sciences, both in colleges and universities and in medical schools, and biological sciences in medical schools were the fields in which toxic waste facilities most often received "adequate" ratings. Again, the modal response for

Figure 17
Adequacy of air decontamination (e.g., fume hoods), by discipline: 1988



*Detail on other responses appears in the appendix tables.
Note: Because of space limitations, values of less than 5 percent are not shown.
Reference: Appendix table 5-11
Source: National Science Foundation, SRS

Figure 18
Adequacy of toxic waste disposal, by discipline: 1988



*Detail on other responses appears in the appendix tables.
Note: Because of space limitations, values of less than 5 percent are not shown.
Reference: Appendix table 5-12
Source: National Science Foundation, SRS

all fields was "generally adequate." The disciplines in which this area was most often rated "inadequate" were physical, agricultural, and biological sciences in colleges and universities (19 percent to 22 percent).

Effects of Facilities Needs

The effects of facilities constraints on the research programs at the institutions were mentioned less often than some of the themes (such as renovation backlogs and the need for additional research space) which were cited above. Where the effects of facilities needs were mentioned, they most often focused on two areas: faculty recruitment and restriction of the research enterprise.

These issues were also cited in NSF's 1986 facilities report. While deans and research administrators were not specifically asked about the effects of facilities needs on the recruitment of personnel in the 1986 survey, 31 percent of research administrators and from 6 to 38 percent of deans in S/E fields spontaneously mentioned this during their interviews. The effects of facilities on the recruitment of faculty and/or graduate students were most often mentioned in the 1986 survey by physical sciences deans, but were mentioned by one-fourth or more of respondents in all but two disciplines.

A number of factors contribute to the competition for faculty in science and engineering fields, including, among others, institutional and departmental reputation, salary, and geographic location. In addition, many disciplines find themselves competing with private industry for scientists and engineers. According to the institutions, research facilities also play a significant role in the recruitment process. Examples of comments on this topic from responses to the 1988 survey are:

- *You need the faculty to write proposals...and you cannot recruit such faculty without them having appropriate facilities to accomplish their work. (Public doctorate-granting university)*
- *...to attract and keep top-notch faculty requires first rate facilities, or a commitment to move in that direction. (Private doctorate-granting university)*

In the 1986 NSF research facilities survey, more than three-fourths of research administrators and deans reported that their facilities problems limited the number and types of projects that could be undertaken. Responses to the 1988 survey indicate that this is still a concern of the institutions. Examples from respondents to this survey about limitations on the research program resulting from inadequate facilities include:

- *...limitations in research facilities...restrict the research opportunities and reduce the competitiveness of well qualified researchers. (Public, non-doctorate-granting university)*

Table 20. Comparison of needed vs. planned repair/renovation, by institution type and control: 1988-89

Institution type and control	Repair, renovation (R&R) needs and plans					
	Existing R&D space		Total cost of:**			Ratio of deferred: planned R&R
	Needing R&R as of 1988*	Planning R&R for 1988 and 89	All needed R&R	All planned R&R	Difference (deferred R&R)	
	(NASF in thousands)		(Dollars in millions)			
Total	44,600	9,670	$3,584	$777	$2,807	$3.60:1.00
Doctorate-granting	43,000	9,480	3,455	762	2,693	3.50:1.00
Top 50	23,400	5,050	1,880	406	1,474	3.60:1.00
Other	19,600	4,430	1,575	356	1,219	3.40:1.00
Non-doctorate-granting	1,600	190	129	15	114	7.60:1.00

*From respondent reports of the percentage of 1988 R&D space needing limited or major repair and renovation.

**All estimates use $80.35 per square foot as the unit cost of repair and renovation. This rate was calculated by dividing the total cost of all planned R&R in 1988 or 1989 by the total NASF of planned R&R.

Note: Details may not sum to total due to rounding.

Source: National Science Foundation, SRS.

- *We are now faced with a situation where space and facilities are the limiting factors for continued growth of [research] activities. (Public, doctorate-granting university)*

- *...the university's research program will begin to plateau or decrease because of the lack of space. (Public, doctorate-granting university)*

Relationship Between Current Facilities Condition and Planned Facilities Repair/Renovation

This section examines the relationship between the current condition of research facilities, discussed earlier in this chapter, and institutions' planned repair/renovation activities for 1988 and 1989, as described previously in Chapter 3. The basic relationship is that, while 39 percent of the research square footage nationally was reported as needing limited or major repair or renovation, repair/renovation projects planned for 1988 or 1989 will encompass only 9 percent of existing research space. This means, apparently, that 30 percent of all current research space needs repair or renovation but will not receive it during the next 2 years.

Specifically, a total of 44.6 million net assignable square feet (NASF) of research space were reported to be in need of repair/renovation in 1988, of which 9.7 million NASF (22 percent) were actually scheduled for repair/renovation work in 1988 or 1989 (table 20). Assuming the cost per square foot for repair/renovation would be the same for other needed projects as for projects already planned, the estimated cost of performing all needed repair/renovation in 1988-89 would be $3.6 billion. Comparing this figure to the total of all planned repair/renovation indicates that, for every dollar institutions plan to spend for repair/renovation of research facilities in 1988-89, an additional $3.60 in needed repair/renovation is being deferred. The level of deferred repair/renovation is about the same for the top 50 R&D performers ($3.60 to $1.00) as for other doctorate-granting institutions ($3.40 to $1.00), and it is about twice those levels among non-doctorate-granting institutions ($7.60 to $1.00).

The disciplines with the lowest rates of deferred repair/renovation (i.e., the ones whose planned repair/renovation projects come closest to meeting the estimated need in the discipline) are the medical sciences ($2.10 to $1.00) and the biological sciences ($2.40 to $1.00), (table 21). At the other extreme, disciplines with comparatively high rates of deferred repair/renovation include the agricultural sciences ($15.20 to $1.00), the environmental sciences ($5.10 to $1.00), and what might be called the

Table 21. Comparison of needed vs. planned repair/renovation, by discipline: 1988-89

Disciplines	Repair and renovation (R&R) needs and plans					
	Existing R&D space		Total cost of:**			Ratio of deferred: planned R&R
	Needing R&R as of 1988*	Planning R&R for 1988 and 89	All needed R&R	All planned R&R	Difference (deferred R&R)	
	(NASF in thousands)		(Dollars in millions)			
Total	44,600	9,670	$3,588	$777	$2,791	$3.60:1.00
Engineering	6,000	1,390	522	121	401	3.30:1.00
Physical sciences	5,600	1,520	548	126	422	3.30:1.00
Environmental sciences	2,600	440	146	24	122	5.10:1.00
Mathematics	200	40	20	4	16	4.00:1.00
Computer science	500	90	36	7	29	4.10:1.00
Agricultural sciences	8,300	510	357	22	335	15.20:1.00
Biological sciences	9,000	2,640	576	168	408	2.40:1.00
Medical sciences	7,700	2,480	785	254	531	2.10:1.00
Psychology	1,000	100	103	11	92	8.40:1.00
Social sciences	1,300	100	112	8	104	13.00:1.00
Other sciences, n.e.c.	1,600	360	139	31	108	3.50:1.00

*From respondent reports of the percentage of 1988 R&D space needing limited or major repair and renovation.

**Estimated costs of planned R&R were reported by the survey respondents. Estimates for needed R&R were obtained by multiplying the square footage needing R&R by the cost per square foot of planned R&R.

Note: Details may not sum to totals due to rounding.

Source: National Science Foundation, SRS.

office-based sciences, mathematics ($4.00 to $1.00), computer science ($4.10 to $1.00), psychology ($8.40 to $1.00), and the social sciences ($13.00 to $1.00).

Relationship Between the Adequacy of the Current Amount of Research Space and Institution Plans for Construction of Additional Space

This section examines the relationship between institutions' perceptions of the adequacy of their current amount of research space and their plans for construction of new research space in 1988 or 1989. The basic relationship, as one might expect, is that the number of institutions actually planning new construction in 1988-89 in a given discipline is usually considerably smaller than the number that describe their existing space in the discipline as insufficient (i.e., as either inadequate in amount or as nonexistent, but needed). Thus, the number of institutions planning new construction in 1988-89 ranges from 9 in mathematics (and also in psychology) to 108 in the biological sciences, and averages 41 across all 11 S/E disciplines (see Appendix table 3-3), while the number reporting insufficient space ranges from 37 in the agricultural sciences to 228 in the biological sciences, and averages 126 across all disciplines (see table 23).

The purpose of this analysis is to examine the extent to which institutions that have a perceived need for additional space in a discipline also have actual plans to address the need through new construction in the near future. First, however, it must be noted that need for additional space is not the only reason an institution might have for new construction. As noted earlier in Chapter 3, some new construction is intended to replace or upgrade existing research space, without necessarily increasing the total amount of research space available in the affected discipline(s). Thus, of the total of $3.4 billion of planned construction in 1988-89, $1.1 billion (32 percent) was reported in disciplines (within institutions) where the current amount of space was not reported to be insufficient.

The extreme case was psychology, where only 11 percent of the institutions that reported plans to construct new research space in that discipline also reported that the current amount of space is insufficient (table 22, first data column). This suggests that most of the planned construction in psychology is designed to upgrade animal quarters, replace obsolete buildings, upgrade labs, etc. -- purposes other than increasing the total amount of research space. Computer science is at the other end of the spectrum, where the need for additional space is the major factor driving new construction. In that discipline, fully three-fourths of the institutions that plan new construction in 1988-89 also report insufficient current space.

Among institutions that report a need for more space in a discipline, the percent also reporting plans to initiate construction of additional space in 1988 or 1989 range from less than 1 percent in psychology to 46 percent in agricultural sciences (table 22). In most disciplines, doctorate-granting institutions that need more space are

Table 22. Relationship between adequacy of the amount of current research space and planned construction of new R&D space in 1988 or 1989, by discipline and institution type

Disciplines	Of institutions planning construction in 1988 or 1989, percent reporting current space as inadequate*	Of institutions reporting current space as inadequate,* percent planning construction in 1988 or 1989			
		Total	Doctorate-granting		Non-doctorate-granting
			Top 50 in R&D	Other	
Engineering	87%	26%	45%	21%	18%
Physical sciences	56	20	32	26	8
Environmental sciences	55	14	14	17	9
Mathematics	56	8	9	8	0
Computer science	75	11	8	18	6
Agricultural sciences	46	46	58	33	57
Biological sciences	56	27	32	38	13
Medical sciences	53	36	62	33	0
Psychology	11	<1	0	2	0
Social sciences	59	7	0	18	2
Other sciences, n.e.c.	67	26	10	28	-**

*Includes institutions that rated their current amount of R&D space in the discipline as either "inadequate" or as "nonexistent, but needed."

**Not applicable: no institutions in this category reported inadequate space in this discipline.

Source: National Science Foundation, SRS.

Table 23. Comparison of needed vs. planned construction of research facilities among institutions: 1988-89

Disciplines	Institutions with both insufficient space and plans for new construction*		All institutions with insufficient research space[1]		Cost difference (deferred construction)	Ratio of deferred: planned construction
	Number of institutions	Cost of planned construction	Number of institutions	Cost of needed construction[2]		
	(Dollars in millions)					
Total[3]	--	$2,336	--	$8,131	$5,795	$2.48:1.00
Engineering	39	353	151	1,086	733	2.01:1.00
Physical sciences	38	388	192	1,583	1,195	3.08:1.00
Environmental sciences	18	124	127	817	693	5.58:1.00
Mathematics	5	3	82	51	48	16.00:1.00
Computer science	18	67	158	626	521	6.37:1.00
Agricultural sciences	17	150	37	265	115	0.77:1.00
Biological sciences	61	400	228	1,203	803	2.01:1.00
Medical sciences	41	795	113	1,937	1,142	1.44:1.00
Psychology	1	1	129	181	180	180.00:1.00
Social sciences	10	17	135	176	159	9.35:1.00
Other sciences, n.e.c.	10	39	39	204	165	4.23:1.00

[1] Insufficient space includes institutions reporting their current research space in the discipline as inadequate in amount or as nonexistent, but needed. Plans for new construction refers to plans to begin construction of new research space in the discipline in 1988 or 1989.

[2] Estimates were derived by multiplying per institution construction costs (as reported by institutions that plan construction in the discipline in 1988 or 1989) by the number of institutions reporting insufficient current space. To account for institution size differences, estimates were computed separately by institution type within discipline.

[3] Ratings of the adequacy of the amount of space were collected for individual S/E disciplines only, and not for total S/E space.

Note: Detail may not sum to totals because of rounding.

Source: National Science Foundation, SRS.

more likely to have plans for new construction than is the case for non-doctorate-granting institutions.

The number of institutions reporting inadequate amounts of research space and planned new construction in 1988 and 1989, and the cost of that construction ($2.3 billion) are shown in table 23 (first two columns). If all institutions with insufficient research space were able to begin projects to build additional space, at the same cost per institution[18] as institutions that do plan new construction projects in 1988-89, the estimated total construction cost would be $8.1 billion. This is about three and one-half times the $2.3 billion of construction actually planned by these institutions (table 23, third and fourth columns). The shortfall, which might be described as **deferred construction**, amounts to $2.48 of needed-but-not-planned construction for every $1.00 of planned construction.

The rate of deferred construction varies widely by discipline. In the agricultural sciences, only $0.77 in needed construction is deferred for every $1.00 planned, indicating that spending actually planned for 1988-89 is more than one-half the total that would be required for new construction at all institutions that have insufficient research space in this discipline. Other disciplines with especially low rates of deferred construction are the medical sciences ($1.44 to $1.00), the biological sciences ($2.01 to $1.00), and engineering ($2.08 to $1.00). The "office-based" sciences (mathematics, computer science, psychology, and the social sciences) have the highest rates of deferred construction, all above $8.00 to $1.00. Psychology has by far the highest deferral rate, since the number of institutions that report insufficient current space in that discipline is fairly large (129), but only one of those reporting inadequate space is planning any new construction in that discipline in 1988 or 1989.

[18] The estimate of deferred construction is based on cost per institution rather than cost per square foot, because reliable estimates of needed additional square feet are very difficult to collect.

6. RESEARCH FACILITIES AT HISTORICALLY BLACK COLLEGES AND UNIVERSITIES

HIGHLIGHTS

- Historically black colleges and universities (HBCU's) have 1 million net assignable square feet (NASF) of space for organized research, or 1 percent of the NASF at all institutions.
- HBCUs' projected spending on research facilities construction and repair/renovation during 1988 and 1989 ($42 million) is down substantially from the level reported for the 1986-87 period ($85 million).
- HBCU's receive more than 80 percent of their funds for facilities from government sources, reported less use of institutional funding, and no use of tax-exempt bonds.
- The modal response for the amount of research space in science and engineering disciplines at HBCU's was "generally adequate." An estimated 76 percent of the research space was rated as either suitable for use in the most scientifically sophisticated research or as effective for most purposes.

Historically black colleges and universities (HBCU's) are institutions that were founded primarily for black Americans, although their charters were generally not exclusionary.[19] They have been identified with service to black Americans for at least two decades, with most being 50 to 100 years old. Of the 107 HBCU's, 29 in the continental United States have been identified as having separately budgeted science and engineering research; together, they accounted for $66.3 million in R&D expenditures in 1986.[20] Of these 29 HBCU's, 22 are public institutions and 25 are non-doctorate-granting institutions. All 29 have been included in this survey in order to provide reliable estimates for this group.

Two cautions should be observed in analyzing data from this survey. First, because HBCU's have relatively low amounts of space and construction, percentages based on these small numbers can show large fluctuations. Second, with only 29 institutions in the population, it is relatively easy for data from one institution to dominate the results. This is especially true in areas such as new construction, where institutions typically report zero construction for most disciplines. In response to these problems, the analysis of capital project activity in this chapter will generally focus on overall features of historically black institutions, and will de-emphasize results for specific disciplines.

Amount Of Research Space Available

HBCU's have an estimated 1 million net assignable square feet (NASF) of space[21] used for organized research in the sciences and engineering (table 24). This represents about 1 percent of the 114 million NASF at all research institutions. For HBCU's, the proportion of S/E space used for research represents 19 percent of the total science/engineering space. On a per-institution basis, historically black institutions have a mean of 37,000 NASF of S/E research space.

Table 24. Space for organized research in science/engineering disciplines at historically black colleges and universities: 1988

Disciplines	Total research square feet (in thousands)	Percent of total S/E space used for organized research
Total	1,071	19%
Engineering	152	20
Physical sciences	164	24
Environmental sciences	7	19
Mathematics	12	7
Computer science	49	33
Agricultural sciences	259	43
Biological sciences	223	21
In colleges and universities	140	28
In medical schools	83	15
Medical sciences	159	9
In colleges and universities	30	6
In medical schools	129	11
Psychology	14	12
Social sciences	28	9
Other sciences, n.e.c.	4	3

Source: National Science Foundation, SRS.

The distribution of space in historically black institutions among the various disciplines is roughly similar to that of the institutions overall, with the exception that agriculture has a larger proportion of the NASF (24 percent) among HBCU's than all institutions (16 percent).

[19] As defined by the National Advisory Committee on Black Higher Education and Black Colleges and Universities.

[20] Selected Data on Historically Black Colleges: Academic Year 1986. Prepared by Universities and Colleges Studies Group, Statistical Analysis Section, Division of Science Resources Studies, National Science Foundation. December 1987.

[21] HBCU's represent small proportions of total research NASF and facilities costs; their somewhat different results have little effect on national findings for all institutions.

Construction and Repair/Renovation

While historically black institutions have 1 percent of the NASF, they account for 3 percent of the costs of new construction projects started in 1986 and 1987 (i.e., $71 million out of a total $2.1 billion for all institutions) (table 25). This amounts to a mean of $2.4 million in new construction per institution. HBCU's project $37 million in project completion costs for 1988 and 1989, 48 percent less than 1986 and 1987. Such large fluctuations are relatively common when only a small number of institutions are being measured; since only 29 historically black institutions were studied, a single large project started in 1986 or 1987 at one institution has the capacity to make those years appear unusually high.

Table 25. Construction and repair/renovation in 1986 and 1987 and planned for 1988 and 1989 at historically black colleges and universities

Construction and repair/ renovation	1986 and 1987	1988 and 1989*
Construction projects		
Total project completion costs (in millions)	$ 71	$ 37
Total square feet (in thousands)	475	90
Square feet as percent of available space	44%	8%
Repair/renovation		
Total project completion costs (in millions)	$ 14	$ 5
Total square feet (in thousands)	135	85
Square feet as percent of available space	13%	8%

*Projected.

Source: National Science Foundation, SRS.

A similar finding concerns the total square feet involved in the new construction projects. Their 475,000 square feet in new projects was 5 percent of the 10 million square feet of construction among all institutions, while they represent only 3 percent of project costs.[22] Using a different measure, the square feet of new construction as a percentage of currently available space, the growth in HBCU's was about 44 percent.

The projected growth in square footage in 1988 and 1989 shows a similar pattern to that of costs of new construction. Historically black institutions project a large drop in new construction projects in 1988 and 1989 to bring them to the 1 percent level of all institutions (at 90,000 square feet, compared with 11.8 million). Measuring the square feet of new construction as a percentage of currently available space, their high growth rate in 1986 and 1987 will be offset by a lower (8 percent) growth rate in 1988 and 1989 that is closer to the rates for other institutions.

For repair/renovation projects in 1986 and 1987, the total project completion costs at HBCU's were $14 million, or 2 percent of the repair and renovation costs among all institutions. But, as with new construction projects, repair/renovation costs are expected to change in 1988 and 1989 (to $5 million) to a level of 1 percent of the projected costs among all institutions. This represents a decline of 64 percent for historically black institutions. (One caution is that projections for repair/renovation may be less accurate than projections for new construction. If repair and renovation projects require less preparation time than new construction, there is an increased possibility that new projects can be adopted that have not yet been planned. This may help to explain why a decline is expected even among all institutions, when inflation would be expected to have the opposite effect.) If the projections for repair/renovation are accurate, the changes reflect a relative shift in priorities between new construction and repair/renovation.

The repair/renovation projects in 1986 and 1987 involved 135,000 square feet, or 13 percent of all research space at historically black institutions. Less space (85,000 square feet, or 8 percent of all research space) is projected to be involved in repair/renovation in 1988 and 1989. This projection could reflect either a general shift in priorities between new construction and repair and renovation, or a difficulty in projecting future repair and renovation efforts.

[22] The disproportionate growth in space as compared to dollar costs is apparently due to strong growth in the agricultural sciences, where large amounts of space may sometimes be added at relatively small cost.

Sources of Funds

The Federal Government is the predominant source of facilities funds for historically black institutions, providing 45 percent of the funds for new construction in 1986 and 1987, and 61 percent of the funds for repair/renovation projects (table 26).[23] HBCU's project, however, that they will receive considerably less of their funds from the Federal Government in 1988 and 1989. Federal funds for new construction are projected to decline to 16 percent, and Federal funds for repair/renovation are projected to decline to 37 percent. Given that large decreases in total funding are projected for both new construction and repair/ renovation, this represents a substantial change in the projected dollar amount of Federal funds (i.e., from $32 million to $6 million for new construction, and from $8 million to $2 million for repair and renovation).

Table 26. Sources of funds for science/engineering research facilities projects at historically black colleges and universities: 1986-1989

Funding sources	Construction		Repair/renovation	
	1986 and 1987	1988 and 1989*	1986 and 1987	1988 and 1989*
Total dollars (in millions) ...	$ 71	$ 37	$ 14	$ 5
Percent of funds from each source				
Federal Government.....	45%	16%	61%	37%
State/local government	36	84	35	44
Private.....	15	0	4	19
Institutional funds.....	3	0	<1	0
Debt financing				
Tax-exempt bonds.....	0	0	0	0
Other debt.....	0	0	0	0
Other sources.....	0	0	0	0

*Projected.

Source: National Science Foundation, SRS.

State and local governments are the second largest source of funding for the historically black institutions, and their proportion is projected to increase. They provided 36 percent of the funds for new construction in 1986 and 1987, and 35 percent of the funds for repair/ renovation; this is roughly similar to their proportion of funding among all institutions (38 percent for new construction, and 27 percent for repair/renovation).

The dollar amount of funding from State and local governments is not expected to change considerably in 1988 and 1989. With the projected diminished Federal share, however, the proportion of State/local funding as compared with all funding is projected to show a large increase. For new construction, there is a projected increase from 36 percent to 84 percent (in dollars, from $26 million to $31 million), and for repair/renovation, an increase from 35 percent to 44 percent (in dollars, a decline from $5 million to $2 million).

Government sources (Federal and State/local) accounted for 81 percent of new construction and 96 percent of repair/ renovation in 1986 and 1987, and are projected at 100 percent of new construction and 81 percent of repair/ renovation in 1988 and 1989.

Private facilities funding amounts to 15 percent of new construction and 4 percent of repair and renovation. Historically black institutions project a decline in private funding for new construction (to zero percent) and an increase for repair and renovation (to 19 percent, although the dollar amount of the increase is only from $.5 million to $.9 million).

Institutional funds account for 3 percent of the funds for new construction and less than 1 percent of funds for repair and renovation, while other sources provide no funds. No funding from other sources is anticipated for 1988 and 1989.

The Condition and Adequacy of Research Facilities

When asked to rate the adequacy of the amount of R&D space, the modal response by historically black institutions is "generally adequate" (table 27).[24] In fact, there is only 1 discipline (environmental sciences) for which this was not the most common response,[25] and there are only two

[23] One historically black institution received an unusually large proportion of funds from the Federal Government for repair and renovation, and if this institution is excluded, the Federal share among HBCU's is reduced to 44 percent. The Federal share for new construction was not affected by excluding this institution.

[24] Readers should note that the percentages in table 27 are often based on extremely small numbers, since some disciplines are offered by few historically black institutions. For that reason, this analysis focuses more on general patterns than on specific disciplines.

[25] In the case of computer science, there were equal numbers of institutions indicating "generally inadequate" and "inadequate or nonexistent, but needed."

Table 27. Adequacy of research space at historically black colleges and universities: 1988

Disciplines	N	Adequate	Generally adequate	Inadequate or nonexistent but needed
		(percent of institutions)		
Engineering	13	27%	55%	18%
Physical sciences	24	10	62	29
Environmental sciences	3	0	33	67
Mathematics	14	17	58	25
Computer science	17	29	36	36
Agricultural sciences	13	27	45	27
Biological sciences				
In colleges and universities	27	13	52	35
In medical schools	2	50	50	0
Medical sciences				
In colleges and universities	8	43	57	0
In medical schools	3	0	100	0
Psychology	14	8	50	42
Social sciences	19	6	50	44
Other sciences, n.e.c.	5	0	75	25

Source: National Science Foundation, SRS.

additional disciplines (computer science and agricultural sciences) for which less than 50 percent of the institutions rate their space as "generally adequate."

Historically black institutions rated 37 percent of their facilities as suitable for use in the most scientifically sophisticated research, and rated an additional 39 percent as effective for most uses, bringing the total for these two categories to 76 percent. Twenty-five percent of the space was rated as needing either limited (18 percent) or major (7 percent) repair or renovation to be used effectively.

7. COMPARISON OF 1986 AND 1988 RESEARCH FACILITIES SURVEYS

HIGHLIGHTS

- The average amount of research space at top 50 R&D institutions increased by about 9 percent from 1986 to 1988.
- Expenditures for **construction** of research facilities at top 50 institutions for the period 1987 through 1989 were estimated to be higher in 1988 than had been projected in 1986. Expenditures for **repair/renovation** of research facilities for this period were estimated to be lower than projected in 1986.
- The share of Federal funds and tax-exempt bonds in the financing of research facilities is similar to the levels projected in 1986. The exception is a slightly lower proportional use of bonds for construction (24 percent compared to the projected 29 percent).
- A majority of respondents in 1986 rated the amount of research space at their institutions as "less than needed." In the current survey, 25 percent to 51 percent of respondents, depending on discipline, rated the amount of space as "inadequate;" additional respondents rated the amount as "adequate" or "generally adequate, with some limitations."

While there are a number of methodological differences between NSF's 1986 and 1988 surveys on academic research facilities, the findings can be compared in a few ways. This chapter relates the findings of the two studies; the comparisons are limited to those which can validly be made, given the sample and questionnaire differences between the two surveys. The Technical Notes section (Appendix A) describes the methodology of the current survey in-depth, and provides a summary of the 1986 approach. A comparison of the 1986 and 1988 surveys is shown in Exhibit A-1 (Appendix A).

Only one group of institutions is directly comparable between the two surveys -- the top 50 in R&D expenditures. Nearly all of them (47) were included in the 1986 survey, and all were included in 1988. The comparisons in this chapter focus on these institutions.

Science and Engineering Research Space

The top 50 R&D institutions are the only subgroup which could be compared in order to assess whether any change in the amount of research space has taken place since 1986 (table 28). Forty-seven of them were included in the 1986 survey, and all were included in 1988. The data show an increase of 9 percent in the average science and engineering research square footage at top 50 universities, from just over 1 million square feet in 1986 to just over 1.1 million in 1988.

Table 28. Comparison of science/engineering research square footage at top 50 R&D institutions: 1986 and 1988 surveys

Year of survey	No. of institutions	Total	Average
		(square feet in thousands)	
1986 survey	47	48,504	1,032
1988 survey	50	56,501	1,130

Source: National Science Foundation, SRS.

Construction and Repair/Renovation Projects

Among top 50 institutions, the **construction** costs reported in the 1988 survey were greater than would be expected, based on the 1986 survey (table 29). Forty-seven of the top 50 schools in the 1986 survey reported plans for projects costing $2.5 billion, or an average of $54.4 million per institution for 5 years. Prorated to 3 years, to provide a basis for comparison with the 1988 survey, the expected cost

Table 29. Comparison of 1987 through 1991 new construction and repair/renovation costs for research facilities at top 50 R&D institutions: 1986 and 1988 surveys

Type of project	1986 Survey				1988 Survey		
	No. of institutions	Total cost 1987-91	Average cost 1987-91	Average 1987-89	No. of institutions	Total cost 1987-89	Average cost 1987-89
		(dollars in millions)				(dollars in millions)	
New construction	47	$2,542	$54.4	$32.6	50	$2,583	$51.7
Repair/renovation	47	1,240	25.5	15.3	50	682	13.6

Source: National Science Foundation, SRS.

would be $32.6 million per institution. In the 1988 survey, however, the top 50 institutions reported an average amount of $51.7 million for the 3-year period including 1987 through 1989. This represents 95 percent of the 5-year projections made in 1986.

In the 1986 survey, the top 50 institutions projected an average repair/renovation cost of $25.5 million for 5 years, or $15.3 million for 3 years. The top 50 schools' 3-year estimate based on 1988 responses is an average of $13.6 million per institution, 11 percent less than the 1986 estimate. This finding is consistent with the anticipated decline in repair/renovation noted in Chapter 3.

Sources of Funds for Construction and Repair/ Renovation

The 1986 survey did not ask institutions to report the proportion of repair, renovation, and new construction costs that would be paid for with institutional funds. The schools reported institutional funds in the 1986 survey according to their source (e.g., State, private) rather than identifying them as institutional. In addition, the 1986 survey did not include categories for "other debt" and "other" sources. For this reason, several categories are not directly comparable. The current survey results do confirm the 1986 finding that public and private institutions differ in their funding sources: public institutions receive more State funding, and private institutions tend to rely more on private sources and tax-exempt bonds.

The proportions of costs that were projected for Federal sources and from tax-exempt bonds, however, are more comparable (table 30). The top 50 R&D universities reported similar proportions of Federal support for future projects in both surveys -- 2 percent in the 1986 survey and 3 percent in the 1988 survey. The proportion of tax-exempt bond financing projected in 1986 was 29 percent, compared to 24 percent in 1988. In both surveys, top 50 institutions anticipated a somewhat higher portion of costs to be financed with bonds compared to those below the top 50.

Among top 50 universities, in 1986, the anticipated Federal portion of repair/renovation costs was 9 percent, compared to 6 percent in the 1988 survey, a slight decline. The 1986 and 1988 projections for tax-exempt bond financing were also similar, 12 percent and 14 percent, respectively.

Table 30. Comparison of funding sources for research facilities at top 50 R&D institutions: 1986 and 1988 surveys

Type of project	Federal	Tax-exempt bonds
New construction		
1986 survey	2%	29%
1988 survey	3	24
Repair/renovation		
1986 survey	9	12
1988 survey	6	14

Source: National Science Foundation, SRS

Condition of Research Facilities

The condition of facilities was reported differently in the 1986 and 1988 surveys. In 1986, deans selected a single category that best represented all space in each field at their institutions. In 1988, responses were based on the distribution of research space across four categories for each field. As a result, in 1986, each institution selected one response, and the responses were not weighted for the amount of research space at the institution. In the current survey, however, the square footage represented by various categories has been added to represent the proportion of research space in each condition category, rather than the proportion of institutions selecting each response. This provides a more accurate picture of the condition of research space. Finally, very specific definitions of each response category were provided in the 1988 survey, but not in the earlier survey.

The methodological differences between the surveys resulted in quite different sets of responses; having to select only one category in one year, and allocating space across the various categories in the other, clearly resulted in non-comparable information. For this reason, the reader is cautioned against using the two surveys to assess change in the condition of facilities.

Adequacy of the Amount of Research Space

In the 1986 telephone survey of science and engineering deans, the amount of space was rated as "about right" by 11 percent to 33 percent of respondents in most fields. Engineering and social science deans were less likely to state that the amount of space was about right (7 percent and 8 percent, respectively). The majority of deans in all fields (64 percent to 93 percent) indicated that they had "less space than needed." In 1988, from 25 percent to 51 percent of academic officials indicated that the amount of research space was "inadequate"; the modal response for nearly all fields was "generally adequate." Engineering was one of the fields in which academic officials most often

rated the amount of research space as inadequate (51 percent) in 1988, consistent with 1986 responses. Similarly, in both years, mathematics was the discipline in which the amount of research space was most likely to be rated as adequate.

APPENDIX A
TECHNICAL NOTES

TECHNICAL NOTES

This section describes the methodology used in this study, including the universe and sample, survey questionnaire, and data collection and response rates. In addition, there is a discussion of some considerations which the reader should bear in mind when interpreting the data presented in this report. A summary of the approach used in NSF's 1986 survey of research facilities at doctorate-granting universities is also included, to facilitate comparisons between the two surveys.

Universe and Sample

The 1988 survey was designed to provide estimates for all research-performing institutions. For this reason, the universe includes a broader range of doctorate-granting institutions than the 1986 survey, as well as adding non-doctorate-granting schools and HBCU's. A sample of approximately 250 institutions was selected in order to provide data on the current status of academic research facilities in the sciences and engineering. The sampling frame for the survey was the FY 1983 Survey of Scientific and Engineering Expenditures at Universities and Colleges file that contains all institutions that offer a master's or doctoral degree in the sciences and engineering, any institution that had separately budgeted research and development (R&D) expenditures of $50,000 or more, and all historically black colleges and universities (HBCU's) with any R&D expenditures. This file represents the most recent available universe survey of R&D expenditures. There are 566 institutions in this frame, and 137 of the universities have medical schools.

All of the historically black colleges and universities were included in the sample with certainty. The remaining 223 sample schools were sampled with varying probabilities to improve the precision of the estimates. The schools were stratified by control of the institution (public vs. private) and by the highest degree awarded. Four strata were formed: public doctorate-granting, public non-doctorate-granting, private doctorate-granting, and private non-doctorate-granting institutions. Academically administered Federally Funded Research and Development Centers were excluded.

Institutions with large amounts of research spending were sampled with certainty. The square root of the total amount of R&D expenditures was the measure of size used to sample the institutions. The impact of the use of total R&D expenditures was examined in each of the disciplines to verify that no institutions with large expenditures in a particular discipline were assigned a measure of size so small as to adversely impact the variance of the estimates in that discipline. The same procedure was used to make sure that the sample size for medical schools is sufficient to generate national estimates in that subgroup. Since institutions that have medical schools very frequently have large total R&D expenditures, this requirement was easily satisfied. Of the 137 schools that have either a separate medical center or a medical program in addition to other programs, 99 were sampled.

The initial allocation of the sampled institutions is shown in table A-1. The allocation was determined by first setting a minimum sample size for each stratum to 25, and then allocating the remaining sample size roughly in proportion to the size of each stratum, in which size is the square root of total R&D expenditures.

Table A-1. Initial sample allocation for 1988 academic research facilities survey

Stratum	Number of institutions	Sample Size		
		Total	Certainty	Probability
Public doctorate	192	111	59	52
Public non-doctorate	116	26	2	24
Private doctorate	131	61	27	34
Public non-doctorate	97	25	3	22
Historically black colleges and universities	30	30	30	0
Total	566	253	121	132

Note: Adjustments were made to the sample following its selection; the final sample distribution is shown in table A-2.

Following the selection of the sample, NSF determined that several of the sampled institutions were out of the scope of the survey. Out-of-scope institutions included those in U.S. territories, military academies, a special research institute operated by an institution but not assigned to any of its campuses, and two highly specialized institutions considered inappropriate, given the nature of their programs. With the elimination of these out-of-scope cases, the final sample size was 244 institutions, of which 29 are HBCU's, and 99 have medical schools. The resulting weighted national total is 524 institutions.

The sampled universities and colleges include all of the 50 institutions with the largest amount of R&D expenditures and 98 of the top 100. They account for more than 75 percent of the total academic R&D expenditures and at least 70 percent of spending in each discipline. Furthermore, all of the 10 largest institutions for any given science or engineering discipline are included in the sample.

The Survey Questionnaire

The National Science Foundation developed a draft research facilities questionnaire, in consultation with several universities and associations. During a workshop with several higher education associations and university representatives in the spring of 1987, the definitions and questionnaire items were revised. The questionnaire was then pretested during site visits to a group of 22 institutions. Agency and contractor personnel met with institutional administrators and staff to discuss the definitions, questions, and survey procedures. Institutional administrators and staff included vice presidents for research, directors of sponsored research, facilities and budget administrators, institutional research directors, science and engineering deans, department chairs, and principal investigators. Advisory panel members participated in several of the pretest site visits. After completion of the pretest phase, the findings of the pretest were presented to the associations, university representatives, and the project's advisory panel, prior to data collection.

The survey questionnaire requested the following information:

- The total net assignable square feet (NASF) of space available in science and engineering disciplines, and the NASF used for organized research;
- The amount of research space that is leased by the institution and the amount housed in temporary facilities;
- The condition of research facilities in each science/engineering (S/E) discipline;
- The adequacy of selected aspects of research facilities, by discipline;
- The project costs, NASF, and sources of funds for repair/renovation and new construction activities initiated in 1986 and 1987, and planned for 1988 and 1989;
- The status of the institutions relative to the cap on tax-exempt bonds (this item is applicable to private universities and colleges only); and
- A narrative description of the institution's facilities needs and the problems they may be having in addressing those needs.

Data Collection and Response Rates

In October, 1987 a letter from Mr. Erich Bloch, Director, NSF, and Dr. James Wyngaarden, Director, NIH, was sent to the president or chancellor of each sampled institution, asking them to participate in the study and to name a coordinator for the survey. Survey materials were mailed to the coordinators November 20 through 24, 1987, with a requested return date of February 1, 1988. The same data were collected separately for medical schools. Each institution identified as having a medical school was sent two forms: a main institution form for reporting all programs other than medicine, and a medical school form. Receipt of the survey materials was confirmed by telephone during the first week of December. A letter reminding coordinators of the requested return date of February 1 was sent 3 weeks prior to the due date. Nonresponse follow-up was conducted from February 8 through March 15, 1988.

After the questionnaires were edited, additional follow-up was conducted to resolve questions or problems with the survey responses. This extensive follow-up was required because of the complexity of the instrument. In addition, many unfinished items were completed during this data retrieval process.

After data collection, additional site visits were conducted, during which NSF and contractor staff members met with survey respondents to discuss the questionnaire, interpretation and reliability of the data provided, and the survey procedures. The purposes of these visits were to (1) obtain information about the data provided to assist in the analysis of the findings, and (2) to obtain information that could be used in planning for the 1990 survey.

The overall response rate for the survey was 90 percent for the main institution form, and 89 percent for the medical school form. As table A-2 indicates, response rates were quite high for all categories. None of the institutional categories achieved response rates of less than 86 percent. Response rates for public and private institutions were similar for this survey. Finally, while the non-doctorate-granting institutions have much less research space than doctorate-granting institutions, both types of institutions showed an equal willingness to participate, and their response rates were the same.

Table A-2. Academic research facilities survey response rates, by type of institution: 1988

Institution type	Sample	Responses	
		Number	Percent
Main Questionnaire			
All	244	220	90
Doctorate-granting	172	155	90
Non-doctorate-granting	72	65	90
Public	155	140	91
Private	89	80	89
Medical School Questionnaire			
All	99	88	89
Public	60	53	88
Private	39	35	90
Historically Black Colleges and Universities	29	25	86

Item Nonresponse

The level of item nonresponse on the survey was low for all variables and for most cases. Only 12 of the 308 academic questionnaires (220 main questionnaires and 88 medical school forms) were missing responses to more than 10 percent of the 340 items on the questionnaire; 73 had missing values on 10 percent (34) or less of the items, and 56 had missing values on 10 variables or less.

For any given item, the number of missing values was very low. Those with the highest number of missing values were the totals for repair/renovation or new construction costs or square footage. This is because the total must be a missing value if any of the eleven disciplines which comprise the total is a missing value. The square footage variables for renovation were somewhat more likely to be missing than the dollar amounts, and as a result, the totals for renovated square feet had the highest level of item nonresponse. The variable with the highest percentage missing was total square footage for renovation for 1988 and 1989, with a 9 percent nonresponse rate. Nearly all other variables had missing values of 4 percent or less.

Missing values were imputed using a "hot-deck" imputation method, in which data are sorted on relevant variables (e.g., sample stratum and R&D square feet) to select donors for the missing values. Following the imputation of missing values, cases for which any item had been imputed were re-edited for range or logic errors. Because the selected donor cases were those closest to the recipients (missing value cases) in the discipline being imputed, a recipient might have more than one donor (e.g., one for engineering and another for psychology). Correlation matrices were produced for imputed and unimputed data to ensure that the use of multiple donors did not have any significant effect on the interrelationships between disciplines. No significant differences in these relationships resulted from the imputation process.

Weighting

Following the completion of data collection, the data were weighted to generate national estimates. The weighting was accomplished by multiplying the base weight, which is the inverse of the probability of selection, by the nonresponse adjustment. The nonresponse adjustments were computed separately by sample stratum, and for main and medical school questionnaires to provide accurate estimates.

Reliability of Survey Estimates

The findings presented in this report are estimates based on the described sample, and, consequently, are subject to sampling variability. If the questionnaire had been sent to a different sample, the responses would not have been identical; some figures might have been higher, while others might have been lower. The standard error of a statistic (an estimate of the sampling variation) is used to estimate the precision of that statistic obtained in a particular sample. If all possible samples were surveyed under similar conditions, intervals of 1.96 standard errors below to 1.96 errors above a particular statistic would include the average results of these samples in 95 percent of the cases. An interval computed in this way is called a 95 percent confidence interval. Coefficients of variation for selected questionnaire items are presented in table A-3. The coefficient of variation, a measure of relative error, is obtained by dividing the standard error of the estimate by the estimate itself.

Data Considerations

An additional factor in the possible errors involved in survey responses relates to nonsampling error. This type of error includes those resulting from reporting and processing of data. In this survey, extensive follow-up with respondents was used to ensure that the data were as accurate as possible.

Table A-3. Coefficients of variation for selected estimates* from the NSF survey of academic research facilities: 1988

Variable	Estimate	Coefficient of Variation
Total research square footage	(in thousands)	
All	113,588	2.713
Doctorate-granting	109,018	2.927
Non-doctorate-granting	4,570	9.743
Public	83,175	2.332
Private	30,413	5.383
Below top 50 in R&D	57,086	3.754
Total repair/renovation costs: FY 1986-87	(in millions)	
All	$863	8.443
Doctorate-granting	818	8.502
Non-doctorate-granting	45	17.551
Public	439	9.021
Private	424	9.226
Below top 50 in R&D	423	14.782
Total new construction costs: 1986-87	(in millions)	
All	$2,063	5.180
Doctorate-granting	1,900	5.640
Non-doctorate-granting	163	11.473
Public	1,364	2.915
Private	699	13.504
Below top 50	875	9.323
Total repair/renovation costs: 1988-89	(in millions)	
All	$777	8.007
Doctorate-granting	741	6.208
Non-doctorate-granting	36	67.751
Public	445	10.740
Private	332	7.320
Below top 50	332	14.553
Total new construction costs: FY 1988-89	(in millions)	
All	$3,399	3.753
Doctorate-granting	3,291	4.046
Non-doctorate-granting	108	27.156
Public	2,116	4.647
Private	1,282	7.402
Below top 50 in R&D	1,542	7.548
Condition of Research Facilities	(pct. of space)	
Suitable for the most highly developed and scientifically sophisticated research	24%	3.170
Effective for most purposes	37%	1.405
Requiring limited repair or renovation	24%	1.982
Requiring major repair or renovation	16%	1.705

*Coefficients of variation are not presented for top 50 R&D institutions or for historically black "eges and universities. Because all of these cases were selected with certainty, there is no sampling error associated with the estimates.

Research Square Footage. The definition of organized research, as specified in OMB Circular A-21 (the form used for calculation of indirect costs) was used in this survey. That definition is as follows: "**Organized research** *means all research and development activities of an institution that are separately budgeted and accounted for. It includes:* (1) **Sponsored research** *means all research and development activities that are sponsored by Federal and non-Federal agencies and organizations...* (2) **University research** *means all research and development activities that are separately budgeted by the institution under an internal application of institutional funds.*"

The definition used does not include department research which is not separately budgeted and accounted for; as a result, it underestimates the total amount of research space. Discussions with institutions during the 1986 survey and the pretest phase of the current survey indicate that most institutions count space used for departmental research as instructional space, and that reporting such data would be difficult and time-consuming for the institutions. Follow-up calls during the 1986 survey indicated that the A-21 definition includes from 70 percent to 100 percent of the research space at most doctorate-granting institutions.

Institutions' facilities recordkeeping systems vary considerably. In general, public institutions are more likely than private ones to have central computerized facilities inventories that allow more accurate reporting of square footage data. Larger private institutions, however, generally do have such systems, often based on space surveys conducted specifically for OMB Circular A-21. Those institutions with smaller research programs do not calculate square footage for OMB Circular A-21, and are less likely to include estimates of the square footage used for organized research in their records. In such cases, the institutions estimated the data for this survey. Table A-4 shows the distribution of sources used by the institutions to report square footage. The percentages sum to more than 100, since some institutions used more than one source in compiling the information.

Capital Projects Involving Research Facilities. Relatively few institutions maintain information on repair, renovation, and construction projects that relate specifically to research facilities. Many capital projects involve both research and nonresearch space. As a result, institutions had to estimate the proportion of a given project that was related to research facilities when the project was not exclusively for research. A guideline for this purpose was included in the questionnaire instructions as follows: *For multi-purpose facilities, prorate the costs to reflect the proportion of R&D space involved in the projects (e.g., if 20 percent of the space involved is used for organized research, report 20 percent of the total project completion costs).*

Table A-4. Sources of square footage data: 1988

Source	Percent
A-21 space survey	32
A-21 proportional calculation based on R&D salaries and wages	3
Facilities inventory based on Facilities Inventory and Classification Manual	27
Facilities inventory not based on FICM	28
Other source	27

Note: "Other sources" included departmental surveys conducted specifically for this study, reviews of university or college architectural drawings or plans, and other methods.

Some projects, such as whole-building renovations or new construction, may take more than one year to complete, and other projects may overlap fiscal years. The projects were allocated to the year in which construction activity began or will begin (e.g., groundbreaking).

Because institutions use different dollar values to identify "major projects," this survey established a guideline to ensure consistency of reporting. Projects with costs of $100,000 or more associated with R&D facilities were included.

Condition and Adequacy of Research Facilities. A number of respondents stated that reports of the condition of facilities and the adequacy of selected aspects of facilities are, by their very nature, subjective. Two persons may have different assessments of the same facility, or different opinions of what is required in order for a facility to be suitable for a particular type of research. Despite the subjectivity involved, these items do capture an overall picture of the current status of facilities. In addition, a small number of institutions indicated that it is conceptually difficult to assess the condition of a research facility without including instrumentation in that assessment. Most respondents, however, indicated that they had no such problem, and were able to report on the condition of the "bricks and mortar."

1986 Research Facilities Survey

This report contains a number of comparisons between the findings of this survey and the 1986 study of academic research facilities. The two studies do vary in methodology, however, and those variations should be considered when making such comparisons. This section provides an overview of the methodology employed in the 1986 study, and exhibit A-1 provides a summary comparison of the two surveys.

The 1986 study of academic research facilities included two surveys conducted under the Higher Education Surveys (HES) system. This survey system, which was in place at the time the Congressional mandate for the study was issued, was used because it presented a viable approach to obtaining information by the first reporting deadline.

A mail survey was conducted with the 165 institutions classified as doctorate-granting in the Higher Education General Information Survey (HEGIS), the frame from which the HES panel was selected. These institutions, according to HEGIS definitions, include those with a significant level and breadth of activity in, and commitment to doctoral-level education as measured by the number of doctorate recipients and the diversity in doctoral-level program offerings. Therefore, it does not include all institutions that award any doctoral degrees. In addition, some institutions, such as health sciences campuses and engineering schools, are classified as specialized, rather than doctorate-granting, by HEGIS.

The mail survey collected quantitative information on:

- the total amount of space available for science and engineering research;
- the total costs of repair, renovation and new construction of research facilities in academic year 1985-86;
- the combined costs of projects planned for the next 5 years (through 1991);
- sources of funds for repair, renovation, and new construction; and
- the age of research facilities since construction or the most recent major renovation.

In the mail survey, data were collected for science and engineering research facilities as a whole, and not for specific disciplines. A response rate of 83 percent was obtained for the mail survey.

A telephone survey was conducted with 80 research administrators and 173 deans representing 318 S/E programs at a subset of the same institutions included in the mail survey. The survey collected reports from the respondents concerning the condition of research facilities, the need for additional research space, problems they may have had in addressing facilities needs, and the effect of facilities needs on their research programs. The telephone survey achieved a response rate of 98 percent for both research administrators and deans.

This report contains no comparisons of the responses of academic officials on the condition of research facilities for the 1986 and 1988 surveys due to differences in the items. The 1986 respondents were asked to select one of four condition categories (excellent, good, fair, or poor) that best described the facilities in each science or engineering field at their institutions. By comparison, the 1988 survey asked that the space available for each discipline be allocated across four categories: (A) suitable for the most highly developed and scientifically sophisticated research in the field; (B) effective for most purposes, but not applicable to category A; (C) effective for some purposes, but requiring limited repair or renovation to be used effectively; and (D) requiring major repair or renovation to be used effectively.

The adequacy of research space variable differs somewhat between the surveys. In 1986, respondents were asked whether the amount of available research space was "more than needed," "about the right amount," or "less than needed." In the 1988 survey, respondents were asked whether the amount was "adequate," "generally adequate," or "inadequate."

The questions dealing with capital projects also differ somewhat. In 1986, repair and renovation were reported separately, while in 1988, these categories were combined. Also, in 1986, institutions were asked to report "major" projects. In 1988, a dollar cut-off was included -- projects with costs associated with R&D facilities of $100,00 or more were included.

In the 1986 survey, four categories of funding sources were used: Federal, State, private, and tax-exempt bonds. Institutional funds, "other debt" and "other" sources were not separate categories in that survey. For this reason, the percentages of funding from each source are not directly comparable for categories other than Federal and tax-exempt bonds.

Exhibit A-1

Comparison of Methodological Aspects
of the 1986 and 1988 Research
Facilities Surveys

ASPECT	1986 APPROACH	1988 APPROACH	COMPARABILITY
Sample	165 doctorate-granting, (HEGIS classification)	244 doctorate- and non-doctorate-granting	Top 50 only comparable group
Data collection approach	Mail survey and telephone survey	Mail survey	
Questionnaire items:			
S/E NASF	N/A	Total & discipline	Not comparable
S/E R&D NASF	Total	Total & discipline	Total comparable
Leased R&D NASF	N/A	Total	Not comparable
Temporary R&D NASF	N/A	Total	Not comparable
Source of R&D NASF data	N/A	Source asked	Not comparable
Condition of R&D facilities	Four condition categories, one choice per discipline	Four condition categories, percent of NASF in each category, by discipline	Not comparable
Adequacy of selected aspects of facilities	Amount of space	Amount of space Data communications Power systems HVAC Air decontamination Toxic waste disposal	Comparability limited Not comparable Not comparable Not comparable Not comparable Not comparable

Exhibit A-1 (continued)

ASPECT	1986 APPROACH	1988 APPROACH	COMPARABILITY
Cost of R&D capital projects	Used term "major" without further definition	Included projects with costs of $100,000 or more	Comparable for top 50 in average cost; not comparable for percent of institutions with repair/ renovation, construction
	Repair, 1986	Repair/renovation, 1986	
	Renovation, 1986		
	New construction, 1986	New construction, 1986	
	Repair, 1987-91	Repair/renovation, 1987	
	Renovation, 1987-91		
	New construction, 1987-91	New construction, 1987	
		Repair/renovation, 1988-89	
		New construction, 1988-89	
NASF of R&D capital projects	Not asked	All projects	Not comparable
Sources of funds for capital projects	Federal, State, private, tax-exempt bonds	Federal, State, private, institutional, tax-exempt bonds, other debt, other	Comparable for percent Federal and percent financed with tax-exempt bonds
Status on tax-exempt bond limit	Not asked	Asked	Not comparable

APPENDIX B
LIST OF SAMPLED INSTITUTIONS

Public, Doctorate-granting Institutions

University of Alaska at Fairbanks	AK
University of Alabama at Birmingham	AL
University of South Alabama	AL
Auburn University	AL
University of Arkansas at Fayetteville	AR
University of Arkansas Medical Sciences Campus	AR
University of Arizona	AZ
San Diego State University	CA
University of California at Berkeley	CA
University of California at Davis	CA
University of California at Irvine	CA
University of California at Los Angeles	CA
University of California at Riverside	CA
University of California at San Diego	CA
University of California at San Francisco	CA
University of California at Santa Barbara	CA
University of California at Santa Cruz	CA
Colorado State University	CO
University of Colorado	CO
University of Connecticut	CT
University of Delaware	DE
Florida State University	FL
University of Florida	FL
Medical College of Georgia	GA
University of Georgia	GA
Georgia Institute of Technology	GA
University of Hawaii at Manoa	HI
Iowa State University of Science and Technology	IA
University of Iowa	IA
University of Idaho	ID
Southern Illinois University at Carbondale	IL
University of Illinois at Urbana	IL
University of Illinois at Chicago	IL
Indiana University	IN
Purdue University	IN
Kansas State University	KS
University of Kansas	KS
University of Kentucky	KY
Louisiana State University	LA
University of Southwestern Louisiana	LA
University of Massachusetts at Amherst	MA
University of Maryland Baltimore Professional Schools	MD
University of Maryland Baltimore County	MD
University of Maryland at College Park	MD
University of Maine at Orono	ME
Michigan State University	MI
Wayne State University	MI
University of Michigan	MI

University of Minnesota	MN
University of Missouri System Office	MO
University of Missouri at Columbia	MO
Mississippi State University	MS
University of Southern Mississippi	MS
University of Mississippi	MS
Montana State University	MT
East Carolina University	NC
North Carolina State University at Raleigh	NC
University of North Carolina at Chapel Hill	NC
University of North Dakota	ND
University of Nebraska at Lincoln	NE
University of Nebraska Medical Center at Omaha	NE
University of New Hampshire	NH
Rutgers, the State University of New Jersey	NJ
New Mexico Institute of Mining and Technology	NM
New Mexico State University	NM
University of New Mexico	NM
SUNY Health Sciences Center at Brooklyn	NY
SUNY at Binghamton	NY
SUNY Health Sciences Center at Syracuse	NY
SUNY at Buffalo	NY
SUNY at Stony Brook	NY
University of Nevada at Reno	NV
Cleveland State University	OH
Northeast Ohio University College of Medicine	OH
Ohio State University	OH
Ohio University	OH
University of Cincinnati	OH
Wright State University	OH
University of Akron	OH
University of Oklahoma	OK
Oregon State University	OR
Pennsylvania State University	PA
University of Pittsburgh	PA
University of Rhode Island	RI
Clemson University	SC
Medical University of South Carolina	SC
University of Tennessee Center for Health Sciences	TN
Lamar University	TX
Texas A & M University	TX
Texas Tech University	TX
University of Texas System Cancer Center	TX
University of Texas at Austin	TX
University of Texas Health Sciences Center at San Antonio	TX
University of Texas Health Sciences Center at Dallas	TX
University of Texas at El Paso	TX
University of Texas Medical Branch at Galveston	TX
University of Utah	UT
Utah State University	UT
Virginia Commonwealth University	VA

University of Virginia	VA
Virginia Polytechnic Institute & State University	VA
University of Vermont and State Agricultural College	VT
University of Washington	WA
Washington State University	WA
University of Wisconsin at Madison	WI
University of Wisconsin at Milwaukee	WI
West Virginia University	WV
University of Wyoming	WY

Private, Doctorate-granting Institutions

California Institute of Technology	CA
Loma Linda University	CA
Stanford University	CA
University of Southern California	CA
Claremont Graduate School	CA
Yale University	CT
George Washington University	DC
Georgetown University	DC
Howard University	DC
Nova University	FL
University of Miami	FL
Atlanta University	GA
Emory University	GA
Mercer University	GA
Morehouse School of Medicine	GA
Illinois Institute of Technology	IL
Northwestern University	IL
University of Chicago	IL
University of Notre Dame	IN
Tulane University	LA
Boston College	MA
Boston University	MA
Brandeis University	MA
Harvard University	MA
Massachusetts Institute of Technology	MA
Tufts University	MA
Woods Hole Oceanographic Institute	MA
Worcester Polytechnic Institute	MA
Johns Hopkins University	MD
Washington University	MO
St. Louis University	MO
Albany Medical College	NY
Duke University	NC
Dartmouth College	NH
Princeton University	NJ
Columbia University Main Division	NY
New York Medical College	NY

New York University	NY
Polytechnic University	NY
Rensselaer Polytechnic Institute	NY
Rockefeller University	NY
St. John's University	NY
University of Rochester	NY
Yeshiva University	NY
CUNY Mt. Sinai School of Medicine	NY
Cornell University	NY
Syracuse University	NY
Case Western Reserve University	OH
University of Dayton	OH
Carnegie-Mellon University	PA
Hannemann University	PA
Thomas Jefferson University	PA
University of Pennsylvania	PA
Brown University	RI
Meharry Medical College	TN
Vanderbilt University	TN
Southern Methodist University	TX
Texas Christian University	TX
Baylor College of Medicine	TX
Marquette University	WI
Medical College of Wisconsin	WI

Public, Non-doctorate-granting Institutions

Alabama A & M University	AL
University of Arkansas at Pine Bluff	AR
Arkansas State University	AR
California State University at Chico	CA
San Francisco State University	CA
California State University at Fullerton	CA
San Jose State University	CA
University of the District of Columbia	DC
Florida A & M University	FL
University of West Florida	FL
Albany State College	GA
Western Illinois University	IL
Kentucky State University	KY
Murray State University	KY
Grambling State University	LA
McNeese State University	LA
Southern University and A & M College	LA
Southeastern Massachusetts University	MA
University of Massachusetts at Boston	MA
Morgan State University	MD
University of Maryland Eastern Shore	MD
Eastern Michigan University	MI

Moorhead State University	MN
Jackson State University	MS
Mississippi Valley State University	MS
Alcorn State University	MS
North Carolina Agricultural and Technical State University	NC
North Carolina Central University	NC
University of North Carolina at Charlotte	NC
CUNY Brooklyn College	NY
SUNY College at Buffalo	NY
SUNY College at New Paltz	NY
University of Nevada at Las Vegas	NV
Youngstown State University	OH
Lincoln University	PA
Edinboro University	PA
South Carolina State College	SC
Tennessee State University	TN
Southwest Texas State University	TX
Prairie View A & M University	TX
University of Houston at Clear Lake	TX
Texas Southern University	TX
James Madison University	VA
Virginia State University	VA
Norfolk State University	VA

Private, Non-doctorate-granting Institutions

Tuskegee University	AL
Harvey Mudd College	CA
Pomona College	CA
Occidental College	CA
Colorado College	CO
Gallaudet University	DC
Rollins College	FL
Lake Forest College	IL
Drake University	IA
Grinnell College	IA
Dillard University	LA
Wellesley College	MA
Williams College	MA
Wentworth Institute of Technology	MA
Augsburg College	MN
Canisius College	NY
Barnard College	NY
Vassar College	NY
Xavier University	OH
Pacific University	OR
Haverford College	PA
Saint Joseph's University	PA
Swarthmore College	PA

Fisk University	TN
Middlebury College	VT
Walla Walla College	WA
Lawrence University	WI
Milwaukee School of Engineering	WI

Historically Black Colleges and Universities

Alabama A&M University	AL
Tuskegee University	AL
University of Arkansas at Pine Bluff	AR
Howard University	DC
University of the District of Columbia	DC
Florida A&M University	FL
Albany State University	GA
Atlanta University	GA
Morehouse School of Medicine	GA
Kentucky State University	KY
Dillard University	LA
Grambling State University	LA
Southern University and A&M College	LA
Morgan State University	MD
University of Maryland-Eastern Shore	MD
Alcorn State University	MS
Jackson State University	MS
Mississippi Valley State University	MS
North Carolina Ag and Tech University	NC
North Carolina Central University	NC
Lincoln University	PA
South Carolina State College	SC
Tennessee State University	TN
Fisk University	TN
Meharry Medical College	TN
Prairie View A&M University	TX
Texas Southern University	TX
Virginia State University	VA
Norfolk State University	VA

APPENDIX C

FACILITIES REQUEST AND APPROVAL PROCESS

FACILITIES REQUEST AND APPROVAL PROCESS

Many colleges and universities are renovating existing research facilities or constructing new space in an attempt to address their problems with the condition and adequacy of research facilities described in Chapter 5. During the site visits for this survey, a great deal was learned about the request and approval process by which this is accomplished. In addition, many institutions responded to the survey request for descriptions of their facilities approval process. This chapter reviews the general process by which capital projects are requested and approved.

While some institutions' facilities project approval process can best be described as "catch as catch can," in the words of one respondent, most universities and colleges do have a system in place for processing these requests and some others are starting to adopt a more formal system.

In general, facilities requests originate at the department level and are referred to the appropriate dean who reviews these requests and determines the relative need or priority for each, and may eliminate some requests. The dean then refers the approved requests to the next level, which may be a facilities planning committee, an administrative officer for facilities or capital planning, or a provost. Larger institutions were more likely to indicate that they had an internal planning committee, in addition to an administrative officer, whereas smaller institutions tended to refer the requests solely to an administrative officer. Projects approved at this level are then referred to the president/chancellor level for approval, prior to submission to a Board of Regents or Trustees.

An additional step of system-level approval may be required for institutions which are part of a multi-campus system. For public institutions, this institutional approval process is followed by State legislature review for larger projects; the dollar amount of projects which need legislative approval varies from State to State. In some cases, there are two "final" stages of approval for large projects: the first is "concept approval," which results in the allocation of planning funds; when plans are completed, "project approval" is given and the project can be initiated.

Institutional policies vary in the total cost of projects that must go through this entire approval. Many smaller projects (e.g., those costing less than $100,000) may not require approval if they can be accommodated within guidelines established for the use of institutional operating funds. However, if the projects exceed this level, or if the project will be funded with outside monies, the approval process is required at most institutions.

Although this general process is in effect at most of the institutions visited, and is consistent with many of the descriptions provided in survey responses, it may be very formal at some institutions, and very informal at others. Also, the specific levels of approval vary among institutions, as does the meaning of each level of review. For example, the dean's approval at some institutions indicates that the dean has reviewed requests from principal investigators and department chairs and has eliminated some projects that were not considered necessary, or not of the high priority that is given other needs, or could not be approved because of fiscal constraints. This means something very different from the same approval level in an institution where a dean reported that he would "never fail to pass on a request from a department chair." Another example of the variation in what each approval level means: at one site-visit institution, it was stated that the president would not recommend a project to the Regents unless he knew in advance that it would be approved.

The approval of the Board of Regents has different meanings at different institutions, as well. At public institutions, projects approved by the Board of Regents usually go on to the State legislature for further approval and appropriation of funds. At some private institutions, the Board of Regents will not usually approve a project unless the funding (or a majority of it) has been secured or identified.

Information obtained during this survey's site visits indicate that many requests for facilities are not approved, or are delayed, as a result of lack of funds; the large number of comments concerning deferred maintenance backlogs was noted in Chapter 5. Other needed renovations or construction projects are not requested because it is known (or believed) that funds are not available. Inability to service additional debt can also be a factor in funding constraints for capital projects. The following are comments from institutions that bear on the approval and funding problem:

- *One can generalize that for 10 such major [facilities] requests, one or two may be funded. Funding is always the difficulty and there are never sufficient resources to satisfy the needs of every faculty member. These same academic areas are capable of flourishing while others may wither and die. (Private, doctorate-granting university)*

- *Despite the school's extensive building and renovation program underway, there are still millions*

of dollars worth of renovation projects unfunded. (Private, doctorate-granting university)

Some projects may be approved for inclusion in an institution's budget request or 5-year plan, but the necessary funding may not be available. As a result, a number of projects may remain in the budget request for a long time before receiving funding, or may never be funded. When an institution is successful in obtaining approval and funding for a research facilities construction project, there can be a considerable time lag before completion of the facility; public institutions mentioned this more often than private universities and colleges.

- *Due to State and local standard operating procedures, there is a long period of time between the contemplation of a building and its occupancy. (Public, doctorate-granting institution)*
- *The process of acquiring funds from the State for facilities is extremely time-consuming (years). (Public, doctorate-granting institution)*
- *Over time, projects "float" to the top of the list (or die). (Public, doctorate-granting institution)*
- *The difficulty in meeting these space needs is that the time to develop new space is considerably longer than the time available to meet the space needs of faculty, either newly appointed or currently appointed faculty. (Private, doctorate-granting university)*

Several public institutions mentioned the fact that States regard some institutions as "flagship" schools with an emphasis on graduate instruction and research, and others as serving a primarily instructional function. As a result, the "non-flagship" schools may have difficulty in obtaining legislative approval for research-related projects. In addition, when State funds are distributed using a formula based on enrollment, the system works to the detriment of smaller institutions with significant research programs, according to some survey respondents.

When a facility is built, it does not always meet the space needs of the institution, perhaps because of budget constraints that limit the size of the facility which can be constructed, or because of cost overruns or other factors that limit the project. Examples of institutional comments include:

- *Having moved into a new building two years ago, it may seem strange that we have a need for more research space. However, it must be kept in mind that our final square footage request was significantly decreased when the architects incorrectly estimated the cost of the building. (Public, non-doctorate-granting institution)*
- *If additional funding is not obtained [we] will be able to complete only 80 percent of the project. The college will essentially have to scale back the project and thus not be able to complete the major construction designed to complete the campus master plan for research. (Public medical college)*

APPENDIX D
SURVEY QUESTIONNAIRE

OMB # 3145-0101
Expires 2/29/90

1987-88 SURVEY OF SCIENTIFIC AND ENGINEERING R&D FACILITIES AT COLLEGES AND UNIVERSITIES

National Science Foundation
National Institutes of Health

Acting out of concerns raised by the academic community, Congress directed the National Science Foundation to collect and analyze data on the availability, condition, need, cost, and funding sources of science and engineering research and development facilities at colleges and universities. This survey is being conducted in response to that requirement. Institutions are requested to return the completed survey to:

WESTAT, INC.
1650 Research Blvd
Rockville, MD 20850

This information is solicited under the authority of the National Science Foundation Act of 1950, as amended. All information you provide will be used for statistical purposes only. Your response is entirely voluntary and your failure to provide some or all of the information will in no way adversely affect your institution. Where exact data are not available, estimates are acceptable. Your estimates will be better than ours.

We requested that the president or chancellor of your institution designate an individual to coordinate data collection for this survey. The name, title, and address of that person appear below; please correct the label if any of the information is incorrect.

LABEL

If someone other than the person listed above completes this questionnaire, please provide the following information:

Name	Title	Telephone No. and ext.

This form should be returned by February 1, 1988. Your cooperation in returning the survey questionnaire promptly is very important.

If you have any questions regarding this survey, please contact Ms. Mary Collins at Westat's toll-free number 800-937-8281 (800-WESTAT1), or contact Mr. James Hoehn of NSF at 202-634-4673.

How many person hours were required to complete this form?_____

DEFINITIONS AND GUIDELINES

RESEARCH AND DEVELOPMENT (R&D)

R&D for purposes of this survey refers to "organized research" as defined in Section B.1.b of OMB Circular A-21 (revised). "**Organized research** *means all research and development activities of an institution that are separately budgeted and accounted for. It includes:* (1) **Sponsored research** *means all research and development activities that are sponsored by Federal and non-Federal agencies and organizations...* (2) **University research** *means all research and development activities that are separately budgeted by the institution under an internal application of institutional funds.*"

R&D FACILITIES

Using the definition of R&D above, "R&D facilities" refers to the physical plant (e.g., "bricks and mortar," research vessels) in which organized R&D activities take place, including building infrastructure (power, HVAC, etc.), fixed equipment (benches, fume hoods, etc.), and non-fixed equipment costing over $1 million. **Non-fixed equipment costing less than $1 million is not included; these data are gathered in a separate NSF/NIH survey.**

Be sure to report all R&D facilities that are administered by the institution, including facilities that are leased or rented by the institution, facilities at branch campuses, agricultural experiment stations, field and mobile laboratories, etc. **Do not include** facilities that have been designated as Federally-funded R&D Centers (e.g., Brookhaven, Kitt Peak, Fermi, etc.), and do not include facilities that are used by faculty but are not actually administered by the institution (e.g., research space at VA or other non-university hospitals).

R&D SPACE

R&D space refers to the net assignable square footage (NASF) of space in R&D facilities, within which organized R&D activities take place. Specific examples of R&D facilities are:

- research laboratories,
- controlled environment space such as clean or white rooms,
- technical support space such as carpenter and machine shops,
- animal quarters including animal production colonies, holding rooms, isolation and germ-free rooms,
- fixed (built-in) equipment such as fume hoods and benches.

For multi-purpose space such as faculty offices, prorate the space (NASF) to reflect the proportion of use devoted to organized R&D activity. For example, if a room or building is devoted to R&D activity approximately 40% of the time, count 40% of the NASF as R&D space.

Net assignable square feet (NASF). The sum of all areas on all floors of a building assigned to, or available for assignment to, an occupant, including every type of space functionally usable by an occupant, but not including custodial, circulation, mechanical, and structural areas, hallways or bathrooms.

MAJOR REPAIRS/RENOVATIONS AND NEW CONSTRUCTION

Report all R&D repair/renovation projects (repair of deteriorated condition, capital improvement, conversion, etc.) and new construction projects (addition to an existing building, new building) that involve total project costs **associated with R&D facilities** of $100,000 or more. **Include both structural costs and the cost of associated infrastructure such as utilities, data communications, etc.**. For multi-purpose facilities, prorate the cost to reflect the proportion of R&D space involved in the project (e.g., if 20% of the space involved is used for organized research, report 20% of the total project completion costs). For multi-year projects, allocate the entire project completion cost (planning, construction, fixed equipment) to the fiscal year in which the construction activity actually began or is expected to begin (e.g., groundbreaking).

SCIENCE AND ENGINEERING DISCIPLINES

In order to facilitate comparison of data collected in this survey with that of other NSF and NIH survey data, we request that you provide the information in the academic disciplines listed below. The fields listed within each discipline are ILLUSTRATIVE of the science and engineering disciplines. Include all fields within these discipline areas at your institution, even if not listed as an example here. Use your best judgment in reporting fields that cross over discipline categories used in this survey. If you are unable to report separately the data for academic programs, please report the combined data as "Other sciences, n.e.c." and indicate in Item 1 what programs they represent.

See the enclosed crosswalk of NSF-CES program areas for additional detail.

Engineering: Aeronautical and astronautical, agricultural, chemical and petroleum, civil and environmental, computer, electrical and electronic, industrial and management, marine and ocean, mechanical, metallurgical and materials, mining, nuclear, and other engineering programs.

Physical Sciences: Astronomy and astrophysics, chemistry (excluding biochemistry), physics (excluding geophysics), and other disciplinary and multidisciplinary programs within the physical sciences.

Environmental Sciences: Atmospheric and earth sciences, aeronomy, geology, geochemistry, geophysics, meteorology, oceanography, paleontology, seismology, and other disciplinary and multidisciplinary programs within the environmental sciences.

Mathematical Sciences: Algebra, analysis, applied mathematics, foundations and logic, geometry, numerical analysis, statistics, topology.

Computer Sciences: Design, development, and application of computer capabilities to data storage and manipulation, information science.

Agricultural Sciences: Agricultural chemistry, agronomy, animal science, dairy science, forestry, horticulture, range science, wildlife.

Biological Sciences: Anatomy, biochemistry, biophysics, biogeography, botany, ecology, embryology, entomology, genetics, immunology, marine biology, microbiology, nutrition, parasitology, pathology, pharmocology, physiology, zoology, veterinary biology.

Medical Sciences: Anesthesiology, cardiology, dentistry, endocrinology, gastroenterology, hematology, neurology, obstetrics, ophthalmology, pharmacy, preventive medicine and community health, psychiatry, radiology, surgery, veterinary medicine[1], and other health sciences.

Psychology: Animal behavior, clinical, educational, experimental, human development and personality, social.

Social Sciences: Anthropology, economics, history of science, linguistics, political science, socioeconomic geography, sociology.

Other Sciences, n.e.c. (not elsewhere classified): To be used when the multidisciplinary and interdisciplinary aspects make the classification under one primary field impossible.

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[1] Institutions with schools of veterinary medicine should distribute R&D facilities data among the appropriate disciplines (agricultural, biological, and medical sciences) rather than only in medical sciences.

ITEM 1A. PRESENT AVAILABILITY OF R&D FACILITIES IN THE SCIENCES AND ENGINEERING, BY DISCIPLINE

- In column 1 below, please report the total net assignable square feet (NASF) in science and engineering (S/E) disciplines available at your institution. Include space leased by your institution.
- In column 2, report net assignable square feet devoted to **R&D** in S/E disciplines, using the definition of organized research provided on page 2 as the basis for your numbers. Include space leased by your institution.

Disciplines	Total NASF	NASF Used For R&D
Total, S/E Facilities		
Engineering		
Physical Sciences		
Environmental Sciences		
Mathematics		
Computer Science		
Agricultural Sciences		
Biological Sciences		
Medical Sciences		
Psychology		
Social Sciences		
Other Sciences, n.e.c.		

Please specify below the disciplines included in "Other sciences, n.e.c."

ITEM 1B: LEASED R&D SPACE

Please indicate the net assignable square feet of R&D space reported in Item 1 which is leased by your institution.

_____ NASF leased R&D space

ITEM 1C: TEMPORARY R&D FACILITIES

Please indicate the net assignable square feet of R&D space reported in Item 1 which is housed in facilities such as trailers, quonset huts and other temporary buildings.

_____ NASF temporary R&D facilities

ITEM 1D: SOURCE OF SQUARE FOOTAGE DATA

Please indicate the source and year of data on square feet of R&D space.

- ☐ A-21 space survey..... YEAR_____
- ☐ A-21 proportional calculation based on R&D salaries and wages..... YEAR_____
- ☐ Facilities inventory based on Facilities Inventory and Classification Manual (FICM)..... YEAR_____
- ☐ Facilities inventory not based on FICM..... YEAR_____
- ☐ Other (specify)_____.... YEAR_____

ITEM 2. PRESENT CONDITION OF RESEARCH AND DEVELOPMENT FACILITIES

Please indicate the percentage of research facilities reported in Item 1 that falls into each category defined below. Rate the condition of facilities based on the type of research currently conducted in the facility. **Do not include non-fixed research instrumentation costing less than $1 million in your consideration of the status of research facilities in S/E disciplines.**

A -- suitable for use in the most highly developed and scientifically sophisticated research in its field
B -- effective for most purposes but not applicable to category A
C -- effective for some purposes but in need of limited renovation or repair
D -- requiring major repair or renovation to be used effectively

Engineering

A	_____ %
B	_____ %
C	_____ %
D	_____ %
TOTAL	100 %

Physical Sciences

A	_____ %
B	_____ %
C	_____ %
D	_____ %
TOTAL	100 %

Environmental Sciences

A	_____ %
B	_____ %
C	_____ %
D	_____ %
TOTAL	100 %

Mathematics

A	_____ %
B	_____ %
C	_____ %
D	_____ %
TOTAL	100 %

Computer Science

A	_____ %
B	_____ %
C	_____ %
D	_____ %
TOTAL	100 %

Agricultural Sciences

A	_____ %
B	_____ %
C	_____ %
D	_____ %
TOTAL	100 %

Biological Sciences

A	_____ %
B	_____ %
C	_____ %
D	_____ %
TOTAL	100 %

Medical Sciences

A	_____ %
B	_____ %
C	_____ %
D	_____ %
TOTAL	100 %

Psychology

A	_____ %
B	_____ %
C	_____ %
D	_____ %
TOTAL	100 %

Social Sciences

A	_____ %
B	_____ %
C	_____ %
D	_____ %
TOTAL	100 %

Other Sciences, n.e.c.

A	_____ %
B	_____ %
C	_____ %
D	_____ %
TOTAL	100 %

ITEM 3: ADEQUACY OF SELECTED ASPECTS OF R&D FACILITIES

Please rate the adequacy of your R&D facilities to support your current research program in terms of the aspects of the facilities indicated in each column heading. Assign ratings as follows:

1 Adequate -- sufficient to support all the needs of your research in the discipline
2 Generally adequate - sufficient to support most research needs in the discipline, but may have some limitations
3 Inadequate -- not sufficient to support the needs of your research in the discipline
4 Nonexistent, but needed
5 Inapplicable or not needed

NOTE: The assessment of facilities for toxic waste disposal should be made by your institution's bio-safety officer, and should focus on buildings (facilities) and not movable equipment or process.

S/E Discipline	Amount of R&D Space	Data Communication Systems	Power Systems	Building HVAC	Air decontamination (e.g., fume hoods)	Toxic Waste Disposal
Engineering						
Physical Sciences						
Environmental Sciences						
Mathematics						
Computer Science						
Agricultural Sciences						
Biological Sciences						
Medical Sciences						
Psychology						
Social Sciences						
Other Sciences n.e.c.						

ITEM 4A. R&D FACILITIES PROJECTS: FY 1986

Please provide the **project completion costs** (in thousands) for repair/renovation and new construction of **R&D facilities** on which construction was started (e.g., groundbreaking) during your institution's **Fiscal Year 1986**. Include both structural costs and the cost of associated infrastructure such as utilities, data communications, etc. Provide an estimate of the R&D space (net assignable square footage) involved.

Before completing this item, please review the definitions on page 2.

Disciplines	Repair/Renovation		New Construction	
	Project Cost (in thousands)	NASF	Project Cost (in thousands)	NASF
S/E R&D FACILITIES				
Total				
Engineering				
Physical Sciences				
Environmental Sciences				
Mathematics				
Computer Science				
Agricultural Sciences				
Biological Sciences				
Medical Sciences				
Psychology				
Social Sciences				
Other Sciences, n.e.c.				

ITEM 4B. SOURCES OF FUNDING FOR R&D FACILITIES PROJECTS: FY 1986

Please indicate the planned sources of funding for the permanent financing of the total project costs for S/E research facilities listed in the first row of Item 4A (previous page) by reporting the percentage of funding in each category.

Sources	Repair/Renovation	New Construction
	Total = 100%	**Total = 100%**
Federal government	_____%	_____%
State/local government	_____%	_____%
Private donation	_____%	_____%
Institutional funds (operating funds, endowments, etc.)	_____%	_____%
Debt Financing		
Tax-exempt bonds	_____%	_____%
Other debt	_____%	_____%
Other*	_____%	_____%

*Please specify the "other funding sources" below:

_____

_____

ITEM 5A. R&D FACILITIES PROJECTS: FY 1987

Please provide the **project completion costs** (in thousands) for repair/renovation and new construction of **R&D facilities** on which construction was started (e.g., groundbreaking) during your institution's **Fiscal Year 1987** Include both structural costs and the cost of associated infrastructure such as utilities, data communications, etc. Include an estimate of the R&D space (net assignable square footage) involved.

Before completing this item, please review the definitions on page 2.

Disciplines	Repair/Renovation		New Construction	
	Project Cost (in thousands)	NASF	Project Cost (in thousands)	NASF
S/E R&D FACILITIES				
Total				
Engineering				
Physical Sciences				
Environmental Sciences				
Mathematics				
Computer Science				
Agricultural Sciences				
Biological Sciences				
Medical Sciences				
Psychology				
Social Sciences				
Other Sciences, n.e.c.				

ITEM 5B. SOURCES OF FUNDING FOR R&D FACILITIES PROJECTS: FY 1987

Please indicate the planned sources of funding for the permanent financing of the total project costs for S/E research facilities listed in the first row of Item 5A (previous page) by reporting the percentage of funding in each category.

Sources	Repair/Renovation	New Construction
	Total = 100%	**Total = 100%**
Federal government	_____%	_____%
State/local government	_____%	_____%
Private donation	_____%	_____%
Institutional funds (operating funds, endowments, etc.)	_____%	_____%
Debt Financing		
Tax-exempt Bonds	_____%	_____%
Other debt	_____%	_____%
Other*	_____%	_____%

***Please specify the "other funding sources" below:**

_____

_____

ITEM 6A. PLANNED R&D FACILITIES PROJECTS: FY 1988 AND 1989

Please provide the **project completion costs** (in thousands) for repair/renovation and construction of **R&D facilities** on which construction will be started (e.g., groundbreaking) during your institution's **Fiscal Years 1988 and 1989**. Include both structural costs and the cost of associated infrastructure such as utilities, data communications, etc. Provide an estimate of the R&D space (net assignable square footage) involved.

Before completing this item, please review the definitions on page 2.

Disciplines	Repair/Renovation		New Construction	
	Project Cost (in thousands)	NASF	Project Cost (in thousands)	NASF
S/E R&D FACILITIES				
Total				
Engineering				
Physical Sciences				
Environmental Sciences				
Mathematics				
Computer Science				
Agricultural Sciences				
Biological Sciences				
Medical Sciences				
Psychology				
Social Sciences				
Other Sciences, n.e.c.				

ITEM 6B. SOURCES OF FUNDING FOR PLANNED R&D FACILITIES PROJECTS: FY 1988 AND 1989

Please indicate the planned sources of funding for the permanent financing of the **total** project costs for S/E **research facilities projects** listed in the first row of Item 6A (previous page) by reporting the percentage of funding to be obtained from each source.

Sources	Repair/Renovation	New Construction
	Total = 100%	**Total = 100%**
Federal government	_____%	_____%
State/local government	_____%	_____%
Private donation	_____%	_____%
Institutional funds (operating funds, endowment, etc.)	_____%	_____%
Debt Financing		
Tax-exempt bonds	_____%	_____%
Other debt	_____%	_____%
Other*	_____%	_____%

***Please specify the "other funding sources" below:**

_____

_____

ITEM 7: LIMIT ON TAX-EXEMPT BONDS

Recent tax reform legislation established a lir on tax-exempt bonds of $150 million per private institution. Has your institution reached the limit on tax-e: ..mpt bonds?

- [ ] Yes
- [ ] No, but expect to within next two fiscal years
- [ ] No, and do not expect to within next two fiscal years
- [ ] Not applicable

ITEM 8: RESEARCH FACILITIES NEEDS

Please use the remaining space to discuss the research facilities needs and objectives of your institution over the next five years. Include in your consideration both your current research program and your anticipated research program. Specific areas of interest include (but are not limited to) the following areas:

1. research facilities needs and objectives, and their relative priority at your institution;
2. the process whereby research facilities needs are identified and met, and any difficulty you face in meeting these needs;
3. whether your institution has made progress over the past three years in addressing research facilities needs;
4. needs related to campus-wide facilities or systems which support research.

Please be specific as to whether the needs or problems are general ones or are specific to particular disciplines.

APPENDIX E
DETAILED STATISTICAL TABLES

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Table 2-1. Number of institutions, total net assignable square feet (NASF) of space in science/engineering (S/E) disciplines, and total NASF used for R&D, by institution type and control: 1988

Institution type and control	Number of institutions	Total S/E NASF	Total R&D NASF
		(NASF in millions)	
Total	524	273.9	113.6
Doctorate-granting	292	244.4	109.1
Top 50 in R&D	50	106.1	56.5
Other	242	138.3	52.5
Non-doctorate-granting	232	29.5	4.6
Public	318	206.4	83.2
Doctorate-granting	190	185.9	80.1
In top 50 in R&D	31	77.0	39.0
Other	158	108.9	41.1
Non-doctorate-granting	129	20.5	3.1
Private	206	67.4	30.4
Doctorate-granting	103	58.4	28.9
In top 50 in R&D	19	29.1	17.5
Other	84	29.4	11.4
Non-doctorate-granting	103	9.0	1.5

Note: Details may not sum to totals because of rounding.

Source: National Science Foundation, SRS.

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Table 2-2. Number of institutions with any assigned space in science/engineering disciplines and number with any assigned R&D space, by discipline and institution type: 1988

Disciplines	Institution type							
	Total		Doctorate-granting				Non-doctorate-granting	
			Top 50 in R&D		Other			
	Any S/E space	R&D space	Any S/E space	R&D space	Any S/E space	R&D space	Any S/E space	R&D space
Total	524	524	50	50	242	242	232	232
Engineering	300	288	44	44	169	168	87	76
Physical sciences	472	445	49	48	194	186	229	211
Environmental sciences	321	298	43	43	162	158	116	96
Mathematics	455	318	48	43	193	146	215	129
Computer sciences	427	333	44	40	176	134	207	159
Agricultural sciences	105	97	24	24	49	49	32	24
Biological sciences	498	469	50	50	219	202	229	217
Medical sciences	278	256	46	46	157	154	75	56
Psychology	471	403	48	46	197	172	226	185
Social sciences	466	360	49	46	198	171	218	144
Other sciences, n.e.c.	109	94	24	24	63	61	22	9

Note: Details may not sum to totals because of rounding.

Source: National Science Foundation, SRS.

Table 2-3. Total net assignable square feet (NASF) of space in science/engineering disciplines, and total NASF used for R&D, by discipline and institution type: 1988

Disciplines	Institution type							
	Total		Doctorate-granting				Non-doctorate-granting	
			Top 50 in R&D		Other			
	Total NASF	R&D NASF	Total NASF	R&D NASF	Total NASF	R&D NASF	Total NASF	R&D NASF
Total	273,851	113,588	106,073	56,502	138,298	52,515	29,482	4,570
Engineering	40,994	16,185	16,987	8,565	19,650	7,083	4,358	538
Physical sciences	35,920	16,374	12,834	7,626	16,052	7,404	7,034	1,344
Environmental sciences	12,468	6,367	5,478	3,509	5,824	2,686	1,167	171
Mathematics	4,935	753	1,311	245	2,507	442	1,116	65
Computer science	4,950	1,454	1,504	618	2,417	669	1,029	167
Agricultural sciences	30,901	17,964	13,645	9,895	15,486	7,701	1,771	368
Biological sciences	46,106	24,208	16,914	11,303	23,369	11,903	5,823	1,002
Medical sciences	65,783	19,347	25,168	9,327	39,547	9,925	1,068	95
Psychology	9,109	3,116	2,649	1,196	4,163	1,501	2,297	418
Social sciences	16,606	3,413	6,414	1,771	6,782	1,320	3,410	322
Other sciences, n.e.c.	6,979	4,407	3,169	2,447	2,501	1,881	409	80

Note: Details may not sum to totals because of rounding.

Source: National Science Foundation, SRS.

Table 2-4. Percent of total net assignable square feet in science/engineering used for organized research, by highest degree granted, control, and R&D expenditures rank: 1988

Disiciplines	Total	Institutional characteristic						
		Highest degree granted		Control		Ranked by FY 1983 R&D expenditures		Historically black institutions
		Doctorate-granting	Non-doctorate-granting	Public	Private	Top 50	Below top 50	
Total	41%	45%	16%	40%	45%	53%	34%	19%
Engineering	39	43	12	39	42	50	32	20
Physical sciences	46	52	19	44	48	59	38	24
Environmental sciences	51	55	15	52	47	64	41	19
Mathematics	15	18	6	15	17	19	14	7
Computer science	29	33	16	25	40	41	24	33
Agricultural sciences	58	60	21	58	51	73	47	43
Biological sciences	53	58	17	50	60	67	44	21
in colleges and universities	49	56	17	47	54	65	40	28
in medical schools	62	62	-	57	70	70	57	15
Medical sciences	29	30	9	25	41	37	25	9
in colleges and universities	25	26	9	23	32	32	21	6
in medical schools	32	32	-	26	45	40	27	11
Psychology	34	40	18	35	32	45	30	12
Social sciences	21	23	9	23	13	28	16	9
Other sciences, n.e.c.	73	76	20	67	86	77	67	3

Source: National Science Foundation, SRS.

Table 2-3. Amount of science/engineering research space that is leased or housed in temporary facilities, by institution type and control: 1988

Institution type and control	Leased R&D space		Temporary R&D space	
	Square feet (in thousands)	Percent	Square feet (in thousands)	Percent
Total	3,770	3%	2,089	2%
Doctorate-granting	3,760	3	2,033	2
Top 50 in R&D	2,112	4	1,022	2
Other	1,648	3	1,011	2
Non-doctorate-granting	11	<1	56	1
Public	2,351	3	1,788	2
Private	1,420	5	301	1

Note: Details may not sum to totals because of rounding.

Source: National Science Foundation, SRS.

Table 3-1. Number of institutions starting any projects to construct new science/engineering R&D space, by institution type and control and year of project start: 1986-89*

Institution type and control	Construction project start year				
	1986	1987	1986 or 1987	1988 or 89 (planned)	1986-89 (4 yr. total)
Total	128	117	192	227	310
Doctorate-granting	92	92	135	179	221
Top 50 in R&D	29	37	40	40	47
Other	63	55	95	139	174
Non-doctorate-granting	36	25	57	48	89
Public	103	78	139	179	231
Doctorate-granting	73	67	102	133	162
Top 50 in R&D	20	24	28	27	30
Other	53	43	74	107	132
Non-doctorate-granting	30	11	37	46	69
Private	25	39	52	48	80
Doctorate-granting	19	25	32	46	59
Top 50 in R&D	9	12	12	13	17
Other	10	13	21	32	42
Non-doctorate-granting	6	14	19	2	21

*Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D related space.

Note: Details may not sum to totals because of rounding.

Source: National Science Foundation, SRS.

Table 3-1a. Number of institutions with any R&D-related new construction starts in 1986 or 1987, and number with any actual or planned construction starts in the four-year period 1986-89, by discipline and institution type

Disciplines	Total		Doctorate-granting				Non-doctorate-granting	
			Top 50 in R&D		Other			
	1986-87	1986-89	1986-87	1986-89	1986-87	1986-89	1986-87	1986-89
Total	192	310	40	47	95	174	57	89
Engineering	79	115	22	32	30	48	26	35
Physical sciences	41	102	14	22	12	46	14	34
Environmental sciences	27	57	6	9	16	25	5	23
Mathematics	3	12	1	4	2	7	0	1
Computer science	28	47	7	9	13	22	9	17
Agricultural sciences	36	58	8	17	23	32	5	9
Biological sciences	57	146	17	27	26	72	14	47
Medical sciences	54	109	18	32	34	74	2	3
Psychology	20	28	3	6	3	8	13	14
Social sciences	18	35	1	2	2	17	15	16
Other sciences, n.e.c.	13	23	7	8	6	16	0	0

Note: Percents may not sum to 100 because of rounding.

Source: National Science Foundation, SRS.

Table 3-2. For projects to construct new R&D space, estimated net assignable square feet (NASF) of R&D space to be created and estimated total cost of the construction of this R&D space, by institution type and control and year of project start: 1986-89*

Institution type and control	Construction project start year					
	1986 or 1987		1988 or 1989 (planned)		1986 to 1989 (4 yr. total)	
	NASF	Cost	NASF	Cost	NASF	Cost
	(NASF in thousands of square feet; cost in millions of dollars)					
Total	9,989	$2,063	11,829	$3,399	21,818	$5,462
Doctorate-granting	8,974	1,900	11,310	3,291	20,284	5,191
Top 50 in R&D	4,378	1,188	5,154	1,857	9,533	3,045
Other	4,596	712	6,156	1,434	10,752	2,146
Non-doctorate-granting	1,014	163	518	108	1,532	271
Public	7,393	1,364	8,736	2,116	16,129	3,480
Doctorate-granting	6,565	1,230	8,230	2,011	14,795	3,241
In top 50 in R&D	3,165	760	3,410	947	6,575	1,707
Other	3,400	470	4,821	1,063	8,221	1,533
Non-doctorate-granting	828	134	505	106	1,333	240
Private	2,596	699	3,093	1,282	5,689	1,981
Doctorate-granting	2,410	670	3,080	1,280	5,490	1,950
In top 50 in R&D	1,213	428	1,744	910	2,957	1,338
Other	1,197	242	1,336	370	2,533	612
Non-doctorate-granting	186	29	13	2	199	31

*Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D related space. Project cost and space estimates are prorated to reflect R&D component only.

Note: Details may not sum to totals because of rounding.

Source: National Science Foundation, SRS.

Table 3-3. Number of institutions starting any projects to construct new science/engineering R&D space, by discipline and year of project start: 1986-89*

Disciplines	Construction project start year				
	1986	1987	1986 or 1987	1988 or 89 (planned)	1986-89 (4 yr. total)
Total	128	117	192	227	310
Engineering	58	29	79	58	115
Physical sciences	24	16	41	68	102
Environmental sciences	19	10	27	33	57
Mathematics	1	2	3	9	12
Computer science	18	10	28	24	47
Agricultural sciences	27	17	36	37	58
Biological sciences	37	31	57	108	146
Medical sciences	28	34	54	78	109
Psychology	1	19	20	9	28
Social sciences	7	11	18	17	35
Other, n.e.c.	7	7	13	15	23

*Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D related space.

Note: Details may not sum to totals because of rounding.

Source: National Science Foundation, SRS.

Table 3-4. For projects to construct new R&D space, estimated net assignable square feet (NASF) of R&D space to be created, and estimated total cost of the construction of this R&D space, by discipline and year of project start: 1986-89*

Disciplines	Construction project start year					
	1986 or 1987		1988 or 1989 (planned)		1986 to 1989 (4 yr. total)	
	NASF	Cost	NASF	Cost	NASF	Cost
	(NASF in thousands of square feet; cost in millions of dollars)					
Total	9,989	$2,063	11,829	$3,399	21,817	$5,460
Engineering	2,409	434	1,903	501	4,312	935
Physical sciences	803	183	1,782	533	2,585	716
Environmental sciences	384	57	427	126	811	183
Mathematics	9	2	34	6	43	8
Computer science	240	61	224	69	464	130
Agricultural sciences	1,542	153	809	216	2,351	369
Biological sciences	1,730	468	2,435	668	4,165	1,136
Medical sciences	1,927	502	3,263	1,083	5,190	1,585
Psychology	134	24	78	29	212	52
Social sciences	203	38	233	62	436	100
Other sciences, n.e.c.	607	140	641	105	1,248	245

*Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D related space. Project cost and space estimates are prorated to reflect R&D component only.

Note: Details may not sum to totals because of rounding.

Source: National Science Foundation, SRS.

Table 3-5. Number of institutions performing major repair/renovation of science/engineering R&D facilities, by institution type and control and year: 1986-89*

Institution type and control	Year of repair/renovation				
	1986	1987	1986 or 1987	1988 or 89 (planned)	1986-89 (4 yr. total)
Total	222	196	289	230	312
Doctorate-granting	174	178	225	191	237
Top 50 in R&D	43	48	48	49	50
Other	131	130	177	142	187
Non-doctorate-granting	47	18	64	38	75
Public	162	133	210	163	224
Doctorate-granting	127	121	163	130	168
In top 50 in R&D	26	29	29	30	31
Other	101	92	134	100	137
Non-doctorate-granting	36	12	47	33	56
Private	59	63	79	66	89
Doctorate-granting	48	58	62	61	70
In top 50 in R&D	18	19	19	19	19
Other	30	39	43	42	51
Non-doctorate-granting	11	6	17	5	19

*Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D related space.

Note: Details may not sum to totals because of rounding.

Source: National Science Foundation, SRS.

Table 3-6. For projects to repair/renovate (R&R) R&D space, estimated net assignable square feet (NASF) of R&D space affected and estimated total cost of this R&R, by institution type and control and year: 1986-89*

Institution type and control	Year of repair/renovation					
	1986 or 1987		1988 or 1989 (planned)		1986 to 1989 (4 yr. total)	
	NASF	Cost	NASF	Cost	NASF	Cost
	(NASF in thousands of square feet; cost in millions of dollars)					
Total	13,713	$863	9,671	$777	23,384	$1,640
Doctorate-granting	13,123	818	9,485	741	22,608	1,559
Top 50 in R&D	5,663	440	5,053	445	10,716	885
Other	7,459	378	4,432	296	11,891	674
Non-doctorate-granting	590	45	186	36	776	81
Public	8,796	439	6,631	445	15,427	884
Doctorate-granting	8,357	402	6,464	410	14,821	812
In top 50 in R&D	2,608	141	2,879	194	5,487	335
Other	5,749	262	3,585	216	9,334	478
Non-doctorate-granting	438	37	167	34	605	71
Private	4,917	424	3,040	332	7,957	756
Doctorate-granting	4,766	415	3,021	331	7,787	746
In top 50 in R&D	3,056	299	2,174	251	5,230	550
Other	1,710	116	847	80	2,557	196
Non-doctorate-granting	152	9	19	2	171	11

*Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D related space. Project cost and space estimates are prorated to reflect R&D component only.

Note: Details may not sum to totals because of rounding.

Source: National Science Foundation, SRS.

Table 3-7. Number of institutions performing major repair/renovation of science/engineering R&D facilities, by discipline and year: 1986-89*

Disciplines	Year of repair/renovation				
	1986	1987	1986 or 1987	1988 or 89 (planned)	1986-89 (4 yr. total)
Total	222	196	289	230	312
Engineering	86	78	119	96	154
Physical sciences	79	54	99	99	144
Environmental sciences	26	25	41	30	55
Mathematics	14	10	24	12	32
Computer science	23	29	48	22	53
Agricultural sciences	24	16	33	26	46
Biological sciences	109	91	139	113	174
Medical sciences	58	7[illegible]	87	78	101
Psychology	26	13	36	20	50
Social sciences	22	16	30	13	38
Other, n.e.c.	9	14	17	14	26

*Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D related space.

Note: Details may not sum to totals because of rounding.

Source: National Science Foundation, SRS.

Table 3-8. For projects to repair/renovate (R&R) R&D space, estimated net assignable square feet (NASF) of R&D space affected and estimated total cost of this R&R, by discipline and year: 1986-89*

Disciplines	Year of repair/renovation					
	1986 or 1987		1988 or 1989 (planned)		1986 to 1989 (4 yr. total)	
	NASF	Cost	NASF	Cost	NASF	Cost
	(NASF in thousands of square feet; cost in millions of dollars)					
Total	13,712	$863	9,671	$777	23,383	$1,640
Engineering	2,751	143	1,393	121	4,144	264
Physical sciences	1,760	107	1,519	126	3,279	233
Environmental sciences	369	21	441	25	810	46
Mathematics	35	3	41	4	76	7
Computer science	185	16	92	7	277	23
Agricultural sciences	637	21	506	22	1,143	43
Biological sciences	3,760	233	2,640	168	6,400	401
Medical sciences	3,300	238	2,480	254	5,780	492
Psychology	258	14	103	11	361	25
Social sciences	184	35	97	8	281	44
Other sciences, n.e.c.	473	31	359	31	832	62

*Findings are limited to projects with estimated total cost at completion of $100,000 or more for R&D related space. Project cost and space estimates are prorated to reflect R&D component only.

Note: Details may not sum to totals because of rounding.

Source: National Science Foundation, SRS.

Table 4-1. Sources of funds for new construction projects on science/engineering research facilities started in 1986 and 1987, by highest degree granted, control, and R&D expenditures rank

Funding sources	Total	Institutional characteristic						
		Highest degree granted		Control		Ranked by FY 1983 R&D expenditures		Historically black institutions
		Doctorate-granting	Non-doctorate-granting	Public	Private	Top 50	Below top 50	
Total cost (in millions)	$2,063	$1,900	$163	$1,364	$699	$1,188	$875	$71
Federal Government	7%	7%	10%	3%	15%	6%	8%	45%
State/local government	38	37	54	56	4	35	42	36
Private	24	24	15	19	33	26	21	15
Institutional funds	14	15	<1	8	26	14	14	3
Debt financing								
Tax-exempt bonds	15	15	20	14	17	16	15	0
Other debt	<1	<1	0	<1	<1	<1	<1	0
Other sources	2	2	0	<1	5	3	<1	0

Note: Percents may not sum to 100 because of rounding.

Source: National Science Foundation, SRS.

Table 4-2. Amount of funding from each source for new construction projects on science/engineering research facilities started in 1986 and 1987, by highest degree granted, control, and R&D expenditures rank

Funding sources	Total	Institutional characteristic						
		Highest degree granted		Control		Ranked by FY 1983 R&D expenditures		Historically black institutions
		Doctorate-granting	Non-doctorate-granting	Public	Private	Top 50	Below top 50	
		(dollars in thousands)						
Federal Government	$147,695	$132,191	$15,505	$40,998	$106,697	$73,613	$74,082	$32,200
State/local government	782,866	694,207	88,600	757,773	25,093	415,907	366,959	25,786
Private	487,441	462,413	25,028	259,891	227,550	306,833	180,608	10,948
Institutional funds	291,264	290,690	573	110,109	181,155	168,059	123,205	2,320
Debt financing								
Tax-exempt bonds	317,330	284,216	33,114	192,790	124,540	189,315	128,015	0
Other debt	3,152	3,152	0	2,429	723	1,009	2,143	0
Other sources	33,147	33,147	0	182	32,965	32,965	182	0

Source: National Science Foundation, SRS.

Table 4-3. Sources of funds for repair/renovation projects on science/engineering research facilities started in 1986 and 1987, by highest degree granted, control, and R&D expenditures rank

Funding sources	Total	Institutional characteristic						
		Highest degree granted		Control		Ranked by FY 1983 R&D expenditures		Historically black institutions*
		Doctorate-granting	Non-doctorate-granting	Public	Private	Top 50	Below top 50	
Total cost (in millions)	$863	$818	$45	$439	$424	$437	$423	$14
Federal Government	3%	3%	8%	3%	3%	3%	4%	61%
State/local government	27	25	70	52	2	11	44	35
Private	12	13	4	3	21	18	7	4
Institutional funds	38	40	7	36	41	38	38	<1
Debt financing								
Tax-exempt bonds	18	18	12	6	30	28	7	0
Other debt	<1	1	0	<1	1	1	<1	0
Other sources	1	1	0	<1	2	2	<1	0

Note: Percents may not sum to 100 because of rounding.

*The proportional distribution of sources of funds for historically black institutions is skewed by Federal support to an institution with a relatively large proportion of repair/renovation costs.

Source: National Science Foundation, SRS.

Table 4-4. Amount of funding from each source for repair/renovation projects on science/engineering research facilities started in 1986 and 1987, by highest degree granted, control and R&D expenditures rank

Funding sources	Total	Institutional characteristic						
		Highest degree granted		Control		Ranked by FY 1983 R&D expenditures		Historically black institutions
		Doctorate-granting	Non-doctorate-granting	Public	Private	Top 50	Below top 50	
		(dollars in thousands)						
Federal Government	$27,562	23,790	$3,773	13,200	14,362	12,477	15,085	$8,416
State/local government	234,643	203,215	31,428	227,898	6,745	49,157	185,486	4,860
Private	105,888	104,233	1,655	15,028	90,860	78,373	27,515	488
Institutional funds	330,487	327,527	2,960	156,288	174,199	169,134	161,353	42
Debt financing								
Tax-exempt bonds	152,602	147,208	5,394	25,848	126,754	120,924	31,678	0
Other debt	4,066	4,066	0	338	3,728	2,303	1,763	0
Other sources	7,706	7,706	0	246	7,460	7,460	246	0

Source: National Science Foundation, SRS.

Table 4-5. Sources of funds for new construction projects on science/engineering research facilities planned for 1988 and 1989, by highest degree granted, control, and R&D expenditures rank

Funding sources	Total	Institutional characteristic						
		Highest degree granted		Control		Ranked by FY 1983 R&D expenditures		Historically black institutions
		Doctorate-granting	Non-doctorate-granting	Public	Private	Top 50	Below top 50	
Total cost (in millions)	$3,399	$3,291	$108	$2,116	$1,282	$1,857	$1,542	$37
Federal Government	7%	7%	4%	9%	3%	3%	11%	16%
State/local government	34	32	91	52	4	29	40	84
Private	23	23	3	10	44	26	18	0
Institutional funds	11	12	2	12	11	11	12	0
Debt financing								
Tax-exempt bonds	19	20	1	15	27	24	14	0
Other debt	5	5	0	1	12	6	4	0
Other sources	1	1	0	1	1	0	2	0

Note: Percents may not sum to 100 because of rounding.

Source: National Science Foundation, SRS.

Table 4-6. Amount of funding from each source for new construction projects on science/engineering research facilities planned in 1988 and 1989, by highest degree granted, control, and R&D expenditures rank

Funding sources	Total	Institutional characteristic						
		Highest degree granted		Control		Ranked by FY 1983 R&D expenditures		Historically black institutions
		Doctorate-granting	Non-doctorate-granting	Public	Private	Top 50	Below top 50	
		(dollars in thousands)						
Federal Government	$222,245	$217,469	$4,776	$190,203	$32,041	$57,821	$164,424	$5,704
State/local government	1,152,215	1,054,369	97,846	1,105,415	46,800	537,399	614,816	30,812
Private	774,449	771,321	3,128	211,092	563,357	490,323	284,126	0
Institutional funds	389,902	388,145	1,757	248,532	141,370	212,567	177,335	0
Debt financing								
Tax-exempt bonds	662,444	661,908	536	322,517	339,927	451,365	211,079	0
Other debt	162,957	162,957	0	14,753	148,204	107,680	55,277	0
Other sources	34,498	34,498	0	23,956	10,542	0	34,498	0

Source: National Science Foundation, SRS.

Table 4-7. Sources of funds for repair/renovation projects on science/engineering research facilities to be started in 1988 and 1989, by highest degree granted, control, and R&D expenditures rank

Funding sources	Total	Institutional characteristic						
		Highest degree granted		Control		Ranked by FY 1983 R&D expenditures		Historically black institutions
		Doctorate-granting	Non-doctorate-granting	Public	Private	Top 50	Below top 50	
Total cost (in millions)	$777	$741	$36	$445	$333	$445	$332	$5
Federal Government	5%	5%	4%	2%	9%	6%	4%	37%
State/local government	32	29	81	54	2	20	47	44
Private	9	9	3	1	19	13	3	19
Institutional funds	39	40	11	34	45	39	38	0
Debt financing								
Tax-exempt bonds	11	12	1	5	19	14	7	0
Other debt	2	2	0	3	1	4	<1	0
Other source	2	2	0	<1	4	3	1	0

Note: Percents may not sum to 100 because of rounding.

Source: National Science Foundation, SRS.

Table 4-8. Amount of funding from each source for repair/renovation projects on science/engineering research facilities planned in 1988 and 1989, by highest degree granted, control, and R&D expenditures rank

Funding sources	Total	Institutional characteristic						
		Highest degree granted		Control		Ranked by FY 1983 R&D expenditures		Historically black institutions
		Doctorate-granting	Non-doctorate-granting	Public	Private	Top 50	Below top 50	
	(dollars in thousands)							
Federal Government	$40,796	$39,202	$1,594	$10,500	$30,296	$27,105	$13,692	$1,761
State/local government	245,932	216,898	29,034	239,852	6,080	90,565	155,367	2,099
Private	69,412	68,158	1,254	6,603	62,809	57,872	11,540	889
Institutional funds	300,980	297,047	3,933	150,753	150,227	175,029	125,951	0
Debt financing								
Tax-exempt bonds	86,200	85,968	232	22,243	63,957	63,371	22,829	0
Other debt	17,648	17,648	0	13,309	4,338	16,976	671	0
Other sources	16,028	16,028	0	1,263	14,764	13,610	2,418	0

Source: National Science Foundation, SRS.

Table 4-9. Status of private institutions relative to the limit on institutional tax-exempt bonds, by highest degree granted and R&D expenditures rank: 1988

Status relative to $150 million limit on tax-exempt bonds	Total (N=206)	Institutional characteristic: Highest degree granted: Doctorate-granting (N=103)	Institutional characteristic: Highest degree granted: Non-doctorate-granting (N=103)	Institutional characteristic: Ranked by FY1983 R&D expenditures: Top 50 (N=19)	Institutional characteristic: Ranked by FY1983 R&D expenditures: Below top 50 (N=187)
Have reached the limit	10%	20%	0%	59%	5%
Have not, but expect to in next two fiscal years	4	8	1	18	3
Have not, and do not expect to in next two fiscal years	86	72	99	24	92

Note: Percents may not sum to 100 because of rounding.

Source: National Science Foundation, SRS.

Table 4-10. Status of private medical schools relative to the limit on institutional tax-exempt bonds, by R&D expenditures rank: 1988

Status relative to $150 million limit on tax-exempt bonds	Total (N=53)	Ranked by FY 1983 R&D expenditures	
		Top 50 (N=15)	Below top 50 (N=38)
Have reached the limit	27%	71%	9%
Have not, but expect to in next two fiscal years	10	14	9
Have not, and do not expect to in next two fiscal years	63	14	82

Note: Percents may not sum to 100 because of rounding.

Source: National Science Foundation, SRS.

Table 5-1. Current condition of research facilities in the sciences and engineering, by discipline: 1988

Disciplines	Condition of facilities			
	Suitable for use in most scientifically sophisticated research	Effective for most uses, but not most scientifically sophisticated	Requiring limited repair/renovation to be used effectively	Requiring major repair/ renovation to be used effectively
	(percent of research space)			
Total	24%	37%	23%	16%
Engineering	26	37	23	14
Physical sciences	26	34	23	17
Environmental sciences	19	40	26	15
Mathematics	29	45	21	6
Computer science	32	35	16	16
Agricultural sciences	21	32	26	20
Biological sciences	27	36	22	15
in universities and colleges	23	36	25	15
in medical schools	36	34	16	13
Medical sciences	24	37	24	16
in universities and colleges	19	41	26	14
in medical schools	25	35	22	17
Psychology	23	44	21	12
Social sciences	16	47	27	11
Other sciences, n.e.c.	16	48	23	14

Note: Percents may not sum to 100 because of rounding

Source: National Science Foundation, SRS

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Table 5-2. Percent of research space suitable for use in the most highly developed and scientifically sophisticated research in its field, by highest degree granted, control, and R&D expenditures rank: 1988

Disciplines	Total	Institutional characteristic						
		Highest degree granted		Control		Ranked by FY 1983 R&D expenditures		Historically black institutions
		Doctorate-granting	Non-doctorate-granting	Public	Private	Top 50	Below top 50	
Total	24%	24%	15%	23%	26%	23%	25%	37%
Engineering	26	26	25	26	26	23	30	52
Physical sciences	26	27	12	26	26	26	26	5
Environmental sciences	19	19	14	[illegible]	25	14	24	0
Mathematics	29	31	6	25	38	25	30	14
Computer science	32	33	29	37	25	27	37	57
Agricultural sciences	21	21	32	21	32	25	17	46
Biological sciences	27	28	12	26	31	26	28	18
in universities and colleges	23	24	12	23	25	23	23	25
in medical schools	36	36	-	34	39	34	38	7
Medical sciences	24	24	8	23	24	20	27	65
in universities and colleges	19	19	8	20	16	16	22	6
in medical schools	25	25	-	25	26	22	28	78
Psychology	23	25	12	23	22	23	23	44
Social sciences	16	17	4	16	16	13	18	24
Other sciences, n.e.c.	16	16	24	12	23	19	13	1

Source: National Science Foundation, SRS.

Table 5-3. Percent of research space which is effective for most purposes, but not for the most scientifically sophisticated research, by highest degree granted, control, and R&D expenditures rank: 1988

Disciplines	Total	Institutional characteristic						
		Highest degree granted		Control		Ranked by FY 1983 R&D expenditures		Historically black institutions
		Doctorate-granting	Non-doctorate-granting	Public	Private	Top 50	Below top 50	
Total	37%	36%	50%	36%	39%	36%	38%	39%
Engineering	37	37	54	38	35	36	39	24
Physical sciences	34	33	50	35	34	29	39	59
Environmental sciences	40	40	43	37	52	45	34	35
Mathematics	45	43	66	47	41	43	46	60
Computer science	35	33	47	36	34	27	41	32
Agricultural sciences	32	32	34	32	20	31	34	24
Biological sciences	36	35	48	35	37	36	35	63
in universities and colleges	36	35	48	37	34	35	37	46
in medical schools	34	34	-	29	42	39	30	90
Medical sciences	37	37	53	35	41	36	37	22
in universities and colleges	41	40	53	42	36	36	45	39
in medical schools	35	35	-	31	42	36	34	18
Psychology	44	41	57	43	45	37	48	41
Social sciences	47	46	58	48	40	45	49	46
Other sciences, n.e.c.	48	48	32	44	55	52	43	18

Source: National Science Foundation, SRS.

Table 5-4. Percent of research space which is effective for some purposes, but in need of limited repair/renovation, by highest degree granted, control, and R&D expenditures rank: 1988

Disciplines	Total	Institutional characteristic						
		Highest degree granted		Control		Ranked by FY 1983 R&D expenditures		Historically black institutions
		Doctorate-granting	Non-doctorate-granting	Public	Private	Top 50	Below top 50	
Total	23%	23%	24%	25%	21%	25%	22%	18%
Engineering	23	23	9	23	22	26	19	16
Physical sciences	23	22	27	23	22	24	22	27
Environmental sciences	26	26	29	29	17	28	25	16
Mathematics	21	21	22	23	15	25	19	21
Computer science	16	17	13	18	14	16	17	7
Agricultural sciences	26	25	26	26	25	27	25	21
Biological sciences	22	22	26	24	19	23	22	15
in universities and colleges	25	25	26	25	26	25	26	23
in medical schools	16	16	-	22	9	17	16	2
Medical sciences	24	24	26	24	23	26	22	8
in universities and colleges	26	26	26	24	31	29	24	29
in medical schools	22	22	-	24	20	24	21	4
Psychology	21	21	24	22	18	22	21	12
Social sciences	27	26	30	26	32	31	22	23
Other sciences, n.e.c.	23	23	18	28	12	21	25	48

Source: National Science Foundation, SRS.

Table 5-5. Percent of research space requiring major repair/renovation to be used effectively, by highest degree granted, control, and R&D expenditures rank: 1988

Disciplines	Total	Institutional characteristic						
		Highest degree granted		Control		Ranked by FY 1983 R&D expenditures		Historically black institutions
		Doctorate-granting	Non-doctorate-granting	Public	Private	Top 50	Below top 50	
Total	16%	16%	11%	16%	14%	16%	15%	7%
Engineering	14	14	12	13	17	15	13	8
Physical sciences	17	18	11	17	19	22	13	9
Environmental sciences	15	15	14	17	6	13	17	49
Mathematics	6	5	7	6	6	6	5	5
Computer science	16	17	11	9	27	30	6	4
Agricultural sciences	20	20	8	20	23	17	24	9
Biological sciences	15	15	13	16	13	15	14	4
in universities and colleges	15	15	13	15	15	17	14	6
in medical schools	13	13	-	16	10	10	16	1
Medical sciences	16	16	13	18	13	18	14	5
in universities and colleges	14	14	13	13	17	19	10	25
in medical schools	17	17	-	20	12	17	16	0
Psychology	12	13	7	12	15	18	9	3
Social sciences	11	11	8	10	12	11	11	6
Other sciences, n.e.c.	14	14	26	16	10	9	20	34

Source: National Science Foundation, SRS.

Table 5-6. Adequacy of the amount of research space, by science/engineering discipline: 1988

Disciplines	Adequacy of amount of R&D space				
	Adequate	Generally adequate	Inadequate	Varied*	Needed, but non-existent
Engineering	9%	39%	51%	0%	2%
Physical sciences	5	50	43	2	0
Environmental sciences	11	46	38	1	3
Mathematics	21	53	25	0	1
Computer science	15	37	47	0	1
Agricultural sciences	11	50	38	1	0
Biological sciences					
in universities and colleges	8	46	46	0	0
in medical schools	4	45	51	0	0
Medical sciences					
in universities and colleges	13	50	37	0	0
in medical schools	1	54	45	0	0
Psychology	17	51	32	0	0
Social sciences	13	49	37	1	1
Other sciences, n.e.c.	9	50	40	0	0

Note: Percents may not sum to 100 because of rounding.

*Varied–some institutions indicated wide variation in the adequacy of facilities (e.g., those in one building were adequate, those in another building inadequate) and were unable to arrive at one rating.

Source: National Science Foundation, SRS.

Table 5-7. Percent of academic officials rating the amount of research space as inadequate, by highest degree granted, control, and R&D expenditures rank: 1988

Disciplines	Total	Institutional characteristic						
		Highest degree granted		Control		Ranked by FY 1983 R&D expenditures		Historically black institutions
		Doctorate-granting	Non-doctorate-granting	Public	Private	Top 50	Below top 50	
Engineering	51%	50%	53%	51%	51%	69%	47%	18%
Physical sciences	43	51	35	45	40	57	41	29
Environmental sciences	38	46	24	50	13	49	37	67
Mathematics	25	36	9	27	21	47	21	17
Computer science	47	49	43	44	51	53	46	33
Agricultural sciences	38	41	28	39	20	50	34	27
Biological sciences								
in universities and colleges	46	49	43	48	42	52	45	35
in medical schools	51	51	-	58	36	67	45	0
Medical sciences								
in universities and colleges	37	41	26	40	27	60	32	0
in medical schools	45	45	-	51	35	61	40	0
Psychology	32	28	36	33	31	37	31	42
Social sciences	37	32	43	36	38	43	36	38
Other sciences, n.e.c.	40	44	0	39	46	42	40	25

Source: National Science Foundation, SRS.

Table 5-8. Adequacy of data communication systems, by discipline: 1988

Disciplines	Adequacy of data communication systems					
	Adequate	Generally adequate	Inadequate	Varied*	Needed, but non-existent	Not needed or inapplicable
Engineering	26%	37%	31%	0%	5%	0%
Physical sciences	12	51	29	2	4	2
Environmental sciences	19	39	26	2	10	5
Mathematics	14	53	29	0	1	3
Computer science	17	51	26	0	5	1
Agricultural sciences	9	49	33	2	7	0
Biological sciences						
in universities and colleges	14	54	27	0	3	3
in medical schools	5	76	19	0	0	0
Medical sciences						
in universities and colleges	12	55	26	0	2	4
in medical schools	10	61	24	0	2	3
Psychology	23	46	24	1	2	4
Social sciences	17	49	25	2	3	5
Other sciences, n.e.c.	19	45	32	1	2	1

Note: Percents may not sum to 100 because of rounding.

*Varied--some institutions indicated wide variation in the adequacy of facilities (e.g., those in one building were adequate, those in another building inadequate) and were unable to arrive at one rating.

Source: National Science Foundation, SRS.

Table 5-9. Adequacy of power systems, by discipline: 1988

Disciplines	Adequacy of power systems					
	Adequate	Generally adequate	Inadequate	Varied*	Needed, but non-existent	Not needed or inapplicable
Engineering	24%	57%	19%	0%	0%	0%
Physical sciences	16	65	14	1	2	2
Environmental sciences	22	52	16	2	4	4
Mathematics	36	40	14	0	0	9
Computer science	30	43	15	0	1	11
Agricultural sciences	17	60	22	1	0	0
Biological sciences						
in universities and colleges	30	49	18	0	0	2
in medical schools	24	61	15	0	0	0
Medical sciences						
in universities and colleges	36	49	12	0	0	3
in medical schools	34	51	13	0	0	2
Psychology	43	46	7	0	0	4
Social sciences	28	50	10	1	0	11
Other sciences, n.e.c.	29	48	21	1	0	1

Note: Percents may not sum to 100 because of rounding.

*Varied--some institutions indicated wide variation in the adequacy of facilities (e.g., those in one building were adequate, those in another building inadequate) and were unable to arrive at one rating.

Source: National Science Foundation, SRS.

Table 5-10. Adequacy of heating, ventilation, and air conditioning (HVAC), by discipline: 1988

Disciplines	Adequacy of HVAC					
	Adequate	Generally adequate	Inadequate	Varied*	Needed, but non-existent	Not needed or inapplicable
Engineering	17%	55%	26%	1%	1%	0%
Physical sciences	12	48	34	2	1	3
Environmental sciences	19	46	27	0	5	2
Mathematics	23	41	20	0	2	15
Compu*er science	26	41	22	0	1	11
Agricultural sciences	7	59	31	1	1	0
Biological sciences						
in universities and colleges	11	55	29	0	3	2
in medical schools	20	56	24	0	0	0
Medical sciences						
in universities and colleges	21	52	22	0	2	4
in medical schools	22	53	22	0	1	2
Psychology	26	47	24	0	1	3
Social sciences	19	52	14	0	1	14
Other sciences, n.e.c.	23	43	31	1	1	0

Note: Percents may not sum to 100 because of rounding.

*Varied--some institutions indicated wide variation in the adequacy of facilities (e.g., those in one building were adequate, those in another building inadequate) and were unable to arrive at one rating.

Source: National Science Foundation, SRS.

Table 5-11. Adequacy of air decontamination (e.g., fume hoods), by discipline: 1988

Disciplines	Adequacy of air decontamination					
	Adequate	Generally adequate	Inadequate	Varied*	Needed, but non-existent	Not needed or inapplicable
Engineering	12%	53%	20%	0%	3%	11%
Physical sciences	14	43	39	1	1	2
Environmental sciences	18	46	20	1	8	7
Agricultural sciences	14	44	30	0	2	9
Biological sciences						
in universities and colleges	11	51	35	0	1	2
in medical schools	17	58	25	0	0	0
Medical sciences						
in universities and colleges	21	45	22	0	0	11
in medical schools	23	48	23	0	0	6
Psychology	18	28	7	0	2	45
Other sciences, n.e.c.	15	27	36	0	1	21

Note: Percents may not sum to 100 because of rounding.

*Varied–some institutions indicated wide variation in the adequacy of facilities (e.g., those in one building were adequate, those in another building inadequate) and were unable to arrive at one rating.

Source: National Science Foundation, SRS.

Table 5-12. Adequacy of toxic waste disposal, by discipline: 1988

Discipline	Adequacy of toxic waste disposal					
	Adequate	Generally adequate	Inadequate	Varied*	Needed, but non-existent	Not needed or inapplicable
Engineering	23%	40%	10%	0%	10%	16%
Physical sciences	23	43	22	1	5	6
Environmental sciences	23	38	15	0	4	20
Agricultural sciences	15	54	20	0	5	6
Biological sciences						
in universities and colleges	22	49	19	0	5	4
in medical schools	28	54	15	0	2	0
Medical sciences						
in universities and colleges	30	41	16	0	3	10
in medical schools	31	45	16	0	2	6
Psychology	20	18	6	0	1	55
Other sciences, n.e.c.	22	25	9	0	9	35

Note: Percents may not sum to 100 because of rounding.

*Varied--some institutions indicated wide variation in the adequacy of facilities (e.g., those in one building were adequate, those in another building inadequate) and were unable to arrive at one rating.

Source: National Science Foundation, SRS

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