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ABSTRACT

This monograph is one in a series of analytical reports presenting findings from the National Science Foundation's 1989-90 National Survey of Academic Research Instruments and Instrumentation Needs. This report documents current status and recent trends in the amounts, costs, and kinds of academic research equipment in seven major science/engineering fields. It also summarizes department heads' assessments of instrumentation needs and trends in these fields. The analysis compares data obtained in the current survey (1989-90) to similar data collected from the same institutions in 1986-87 and 1983-84. The study is limited to research equipment originally costing $10,000 or more per system, excluding equipment in 18 facilities designated as Federally Funded Research and Development Centers. The current data are based on multistage samples of 11,575 instruments from 909 departments and research centers at 79 institutions: 55 colleges and universities and 24 medical schools. The sample data are statistically weighted to represent a universe of institutions that collectively account for over 90 percent of the nation's academic research and development expenditures in engineering, chemistry, physic/astronomy, and the agricultural, biological, computer, and environmental sciences. The survey response rates are 90 percent or more at all sampling levels. A list of sampled institutions is appended. (KR)

ACADEMIC RESEARCH EQUIPMENT AND EQUIPMENT NEEDS IN SELECTED SCIENCE AND ENGINEERING FIELDS: 1989-90

National Science Foundation

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HIGHLIGHTS

INVENTORY AMOUNT. Over the three cycles of this survey, the amount (aggregate purchase price) of academic research equipment in the $10,000 to $999,999 price range has increased from $1.3 billion in 1982-83 to $2.0 billion in 1985-86 to $3.2 billion in 1988-89. After adjustment for inflation, the latter change represents a real inventory increase of 51 percent over this latest 3-year period.

FIELD CHANGES. The largest increases in equipment amounts over the most recent 3-year period were in engineering (74 percent real growth) and chemistry (59 percent). The environmental sciences had the lowest inventory growth rate (26 percent). Intermediate rates, in the 40-47 percent range, were found for the agricultural, biological, and computer sciences and physics/astronomy.

ANNUAL PURCHASES. Despite the expansion of accumulated equipment stocks over the latest 3-year period, 1988-89 annual purchases of research equipment ($831 million) were only 11 percent higher than in 1985-86. This suggests there was a leveling-off or downturn in instrumentation funding during the latter part of this period.

PERCEIVED TRENDS. In all science/engineering fields, most department heads (87 percent, overall) reported in the 1989-90 survey that their research instrumentation needs had increased over the past 3 years. Fewer (69 percent) reported that the amount of research equipment in their units had increased. Only half reported that the overall adequacy of their equipment had improved.

LACK OF NEEDED EQUIPMENT. Although the overall percentage was not as high as in previous surveys, a substantial majority (62 percent) of department heads continued to report important subject areas where faculty investigators are unable to conduct critical experiments because they lacked the necessary equipment. In three fields, reported lack of needed research equipment was as widespread in 1989-90 as it had been 6 years earlier: physics/astronomy, 84 percent of departments; the agricultural sciences, 77 percent; and the environmental sciences, 69 percent.

AREA MOST NEEDING INCREASED SUPPORT. As in previous surveys, the majority of department heads in the biological and agricultural sciences urged increased Federal funding support for research equipment in the $10,000 to $50,000 range. In all other fields, substantial majorities (52 to 81 percent) urged that increased Federal support be directed to "big ticket" items in the $50,000 and over range.

FUNDING. Over the 6-year period encompassed by this survey program, there has been a gradual decline in the relative share of research instrumentation funding from Federal sources, from 53 percent of the total stock in 1982-83 to 48 percent in 1988-89. Instrumentation funding from the largest Federal source, the National Science Foundation, declined from 18 to 15 percent of the total stock. Over the same period, funding from state governments increased from 5 to 9 percent of the total. These shifts differentially benefitted public-sector institutions.

EQUIPMENT TYPES. The current (1988-89) national inventory of academic science/engineering research equipment can be divided into four broad categories of approximately equal total size, in terms of aggregate purchase price: computers, spectrometers, bioanalytical instruments, and all other equipment. Different fields had very different instrumentation profiles. Spectrometers, for example, were essentially nonexistent in computer science but constituted over three-fifths of the total inventory investment in chemistry.

ACADEMIC RESEARCH EQUIPMENT AND EQUIPMENT NEEDS IN SELECTED SCIENCE AND ENGINERING FIELDS: 1989-90

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The 1989-90 National Survey of Academic Research Instruments and Instrumentation Needs was conducted by Westat, Inc., under contract to the National Science Foundation (Contract Number SRS-8821876). Technical and financial support was also provided by the National Institutes of Health.

At NSF, the survey was developed and guided by Judith F. Coakley and Eileen L. Collins, Senior Science Resources Analysts, Division of Science Resources Studies of the Universities and Colleges Studies Group (UCSG).

Paul Seder, NIH Office of Science Policy and Analysis, directed the National Institutes of Health components of the study.

The study also benefitted from the advice of an expert advisory panel. As well as providing many useful recommendations for the design and conduct of the study, several members of the current advisory panel made significant contributions to the development of the equipment classification taxonomy that is used in the data analysis. The members of this panel, together with the Westat project staff, are named on the inside back cover of this report.

The burden of the study's extensive data collection activities was borne largely by the institution-appointed survey coordinators at the 79 sampled institutions, to whom we owe a special debt of gratitude. The institutions that participated in the survey are listed in Appendix A.

SUGGESTED CITATION

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EXECUTIVE SUMMARY

This monograph is one in a series of analytical reports presenting findings from the National Science Foundation's 1989-90 *National Survey of Academic Research Instruments and Instrumentation Needs.* This report documents current status and recent trends in the amounts, costs, and kinds of academic research equipment in seven major science/engineering fields. It also summarizes department heads' assessments of instrumentation needs and trends in these fields.

The analysis compares data obtained in the current survey (1989-90) to similar data collected from the same institutions in 1986-87 and 1983-84. The study is limited to research equipment originally costing $10,000 or more per system, excluding equipment in 18 facilities designated as Federally Funded Research and Development Centers. The current data are based on multistage samples of 11,575 instruments from 909 departments and research centers at 79 institutions: 55 colleges and universities and 24 medical schools. The sample data are statistically weighted to represent a universe of institutions that collectively account for over 90 percent of the nation's academic R&D expenditures in engineering, chemistry, physics/astronomy, and the agricultural, biological, computer, and environmental sciences. The survey response rates are 90 percent or more at all sampling levels.

This triennial equipment survey program is funded jointly by NSF and the National Institutes of Health and is conducted in response to a Congressional directive to the Foundation to: "...*develop indices, correlates or other suitable measures or indicators of the status of scientific instrumentation in the United States and of the current and projected needs for scientific and technological instrumentation*" (P.L. 96-44, Section 7).

AGGREGATE AMOUNT OF EQUIPMENT

In 1988-89, there were approximately 80,000 science/engineering research instrument systems costing $10,000 or more in academic settings, with an aggregate purchase price of about $5 billion. Nearly $2 billion (36 percent) of this total was concentrated in central computer centers and in about 200 other large systems costing $1 million or more per system (observatories, oceanographic research vessels, nuclear science facilities, etc.). These large systems were not included in earlier cycles of the survey, which focussed on instrumentation in the $10,000 to $999,999 price range.

The aggregate purchase price of research equipment in the $10,000 to $999,999 price range was approximately $3.2 billion in 1988-89. This represents a real (inflation-adjusted) increase of 51 percent from the amount found 3 years earlier ($2.0 billion) and is more than twice the amount found 6 years earlier ($1.3 billion). All of the following statistics refer to equipment in this $10,000 to $999,999 price range.

Current (1988-89) instrumentation stocks are most heavily concentrated in the biological sciences (29 percent of aggregate investment), engineering (26 percent), and the physical sciences -- chemistry (17 percent) and physics/astronomy (11 percent). The environmental (8 percent), computer (5 percent), and agricultural (3 percent) sciences account for the remainder.

The largest inventory increases over the latest 3-year period (1985-86 to 1988-89) were found in engineering (74 percent) and chemistry (59 percent). The environmental sciences had the smallest increase (26 percent).

TYPE OF EQUIPMENT

Aggregate investment in academic research equipment in the $10,000 - $999,999 range was distributed across four categories of about equal total size in 1988-89: *computers* (with almost all of computer science's investment and about one-third of the investments of engineering, physics/astronomy, and the environmental sciences); *spectrometers* (with over 60 percent of chemistry's current investment and becoming increasingly prominent there and in most other fields as well); *bioanalytical instruments* (65 percent of the biological sciences' investment and 52 percent of that of the agricultural sciences); and *all other equipment*, including miscellaneous custom-built instrumentation (about half of the total investments of engineering and physics/astronomy).

From 1985-86 to 1988-89, aggregate investment more than doubled for several kinds of equipment: protein synthesizers/sequencers, computer imaging equipment (graphics/CAD/image analysis equipment), and large prototype systems in the $100,000 and over range.

EQUIPMENT NEEDS

Many science/engineering department heads (69 percent) reported in the current survey that the amount of research equipment in their units increased in the past 3 years. However, almost all (87 percent) said their instrumentation needs had grown over this period. In the agricultural and biological sciences, the greatest need continued to be for equipment in the $10,000 to $50,000 range. In all other fields, substantial majorities of department heads (58-81 percent) identified equipment in the $50,000 and above range as being the area where they most needed increased Federal support, up from much lower percentages (24-65 percent) 6 years earlier.

The growing importance of big ticket items was further indicated by the fact that the median purchase price of department heads' three topmost priority equipment needs was $100,000 or above in all fields except the agricultural and biological sciences (where the medians were $35,000 and $50,000, respectively).

The types of equipment department heads reported as being most needed were generally similar to the kinds they already had. However, in most fields, spectrometers constituted a larger proportion of needed than of existing investments. This was especially true in chemistry (where spectrometers constituted 61 percent of the aggregate purchase price of equipment in the current inventory, but an even larger 79 percent of the costs of all top-priority needs) and the environmental sciences (where spectrometers constituted 28 percent of current inventory and 50 percent of top-priority needs).

In all science/engineering fields studied, the main reason for needing new instrumentation was to become abreast of emerging technologies. Thus, 58 percent of all instruments listed as being top-priority needs were needed to "upgrade capabilities (to perform experiments you cannot do now)," rather than just to replace obsolete or worn-out equipment (17 percent) or to expand a research program by acquiring additional copies of existing instrumentation (25 percent). This need to obtain equipment with upgraded capabilities was especially pronounced in the physical sciences -- physics/astronomy (76 percent of the top-priority needs) and chemistry (62 percent).

ADEQUACY OF EXISTING EQUIPMENT

In the current survey, most science/engineering department heads reported that, over the past 3 years, the overall adequacy of their research equipment either remained about the same (32 percent) or improved (50 percent). Only 17 percent experienced an overall decline in this period. Reported improvements in overall adequacy were most widespread in chemistry (71 percent), and were least common in physics/astronomy (41 percent).

Over the 6-year period encompassed by this survey program, there also were some reductions in the percentage of department heads complaining of important subject areas where faculty investigators in their units could not perform critical experiments because they lacked the necessary equipment. Such complaints were very widespread in 1983-84, being made by about 90 percent of chemistry, computer science, and engineering department heads and by about 80 percent of department heads in the agricultural sciences and physics/astronomy. Even in the biological and environmental sciences, well over half of all department heads expressed this complaint.

By the time of the current survey, this problem seemed to have become somewhat ameliorated in several fields. The percentage of department heads making this complaint declined by 30-34 percentage points in chemistry and computer science and by 19 percentage points in engineering. A reduction from 56 percent to 46 percent was seen even in the biological sciences.

Although considerably relieved or reduced in some areas during this 6-year period, the problem of researchers' inability to conduct critical research due to lack of needed equipment certainly was not solved. The overall percentage of department heads complaining of this problem decreased (from 72 percent in 1983-84 to 62 percent in 1989-90), but at the end of the period the percentage was still well above 50 percent in all fields except the biological sciences. In three major fields, perceived shortages of needed research equipment continued to remain as widespread in 1989-90 as they had been 6 years earlier: physics/astronomy (84 percent), agricultural sciences (77 percent), and environmental sciences (69 percent).

ANNUAL EXPENDITURES

After adjustment for inflation, 1988-89 annual expenditures for purchase of science/engineering research equipment ($831 million) were 11 percent higher than they had been 3 years earlier ($678 million).* The largest 3-year increase was in engineering (34 percent). Chemistry and physics/astronomy showed no change in annual equipment purchases, and computer science and the agricultural sciences both had lower equipment expenditures in 1988-89 than in 1985-86. These findings suggest that, although instrumentation stocks continued to accumulate during the subsequent 3 years, annual spending may have leveled off.

From 1982-83 to 1988-89, annual research instrument purchases consistently represented about 10 percent of total R&D expenditures. As a percentage of total R&D spending, equipment purchases were consistently higher in the physical sciences and engineering than in the agricultural, biological, and environmental sciences.

EQUIPMENT COSTS

Although there was little change during 1985-86 to 1988-89 in the overall average (mean) price of instruments in the $10,000 to $999,999 range (it increased from $38,000 to $40,000), significant changes occurred for particular types of equipment. Average unit prices paid for most categories of computing equipment declined (from $49,000 to $45,000 overall), while price increases occurred for several categories of spectrometers and bioanalytical instruments. Especially large increases in average unit prices were seen for NMR spectrometers (from $93,000 to $152,000) and protein synthesizers/sequencers (from $48,000 to $70,000). Although presumably indicative of increased capabilities of the instrumentation being purchased, the unit price increases also indicate increasing costs of doing research that required such instrumentation.

SOURCES OF FUNDS

As instrumentation stocks in the $10,000-$999,999 range accumulated over the study's 6-year period, more than doubling in aggregate purchase price, all funding sources showed substantial absolute increases in aggregate contributions. However, there were some shifts over this period in the relative magnitudes of the contributions of different sources. Overall, the Federal government's share declined, from 53 percent of the total in 1982-83 to 48 percent in 1988-89; this was largely offset by increased funding from state government sources, which grew from 5 to 9 percent of the total. This shift was disadvantageous to private institutions, which received very little benefit from state governments' increased instrumentation funding activity.

The largest relative declines in Federal support were seen in physics/astronomy and engineering, both of which showed declines of more than 10 percentage points. Of the major Federal instrumentation funding sources, NSF showed the largest relative decline, dropping from 18 to 15 percent of the total. Nevertheless, NSF remained the largest Federal funding source for academic research equipment, followed closely by the National Institutes of Health (14 percent of total funding).

*These data refer to purchases of nonexpendable research equipment costing $500 or more per unit.

INTRODUCTION

This report describes recent trends in academic research equipment and equipment needs in seven major fields of science/engineering: the agricultural, biological, computer, and environmental sciences, chemistry, physics/astronomy, and engineering. It is one in a series of reports presenting information from the 1989-90 cycle of the National Survey of Academic Research Instruments and Instrumentation Needs.[1] This triennial survey program, conducted by the National Science Foundation (NSF) with major support from the National Institutes of Health (NIH), is designed to monitor emerging research equipment needs and trends in the amounts, costs, and characteristics of existing academic research equipment in a broad spectrum of science/engineering fields.

Background

When numerous reports during the late 1970s revealed that the research equipment available to scientists and engineers in leading research universities was often inadequate to meet the needs of modern research, Congress turned to the National Science Foundation (NSF) for factual information. The Congress directed the Foundation to "...develop indices, correlates or other suitable measures or indicators of the status of scientific instrumentation in the United States and of the current and projected needs for scientific and technological instrumentation."[2] In response, NSF initiated a feasibility study to determine the best sources of information about the amount, cost, condition, and need for academic research equipment. The National Survey of Academic Research Instruments and Instrumentation Needs was then developed on the basis of the information provided by the feasibility study.

To date, three cycles of the survey have been completed using similar designs and data-gathering instruments. Cycle 1 was conducted in 1983-84; Cycle 2, in 1986-87; and Cycle 3, in 1989-90. Each of these cycles was conducted in two phases. During Phase I (in 1983, 1986, and 1989), information was collected for the physical and computer sciences and engineering. During Phase II (in 1984, 1987 and 1990), information was collected for the biological, agricultural, and environmental sciences, with the biological sciences portion of the data collection including a separately selected sample of medical schools in addition to the sample of nonmedical colleges and universities that provided data for all major science/engineering fields.

Data Considerations

Basic parameters of the 1989-90 survey are described below. Previous cycles of the study used essentially the same parameters.

Institutions. The institution sample consisted of (a) 55 colleges/universities (excluding medical schools) selected to represent the 174 such institutions with 1984 nonmedical R&D expenditures of $3 million or more, and (b) 24 medical schools statistically selected to represent the 92 medical schools with 1982 NIH extramural funding of $3 million or more.[3] At each sampled institution, a study coordinator was identified to oversee all data collection activities.

Departments. Sampled institutions contained a total of 1,597 departments and nondepartmental research centers with at least one item of research equipment costing $10,000 or more in fields encompassed by the study. In four fields that had especially large numbers of departments/centers--engineering and the agricultural, biological, and environmental sciences--a sample of 909 of the 1,318 eligible departments/centers was selected. In the remaining three fields, chemistry, computer science, and physics/astronomy, all of the 279 eligible departments/centers were included in the study. The heads of these 1,188 units were asked to complete a department questionnaire concerning their expenditures, priorities, and needs for research equipment.

[1] In addition to this report on equipment in all major science/engineering fields, three companion reports provide more detailed, disaggregated information about instrumentation trends within subfields of (a) the physical sciences, (b) the biological sciences, and (c) engineering/computer science. A fourth report provides additional information about characteristics of existing equipment (cost, age, condition, usage, maintenance provisions, useful research life, etc.), by type of equipment. Copies of these reports may be obtained from the National Science Foundation. Contact Dr. Eileen Collins, (202) 634-4655.

[2] An Act To Authorize Appropriations for Activities for the National Science Foundation for Fiscal Year 1980, and for Other Purposes. Public Law 96-44, Section 7.

[3] The two institution sampling frames account, respectively, for over 90 percent of all nonmedical academic R&D expenditures and over 90 percent of all NIH extramural funding to medical schools. The 79 sampled institutions are listed in Appendix A.

Instruments. At each institution, inventory information was requested identifying all research instrument systems originally costing $10,000 or more that were inventoried to sampled departments/centers. A total of 54,624 such instruments was identified, from which a sample of 11,575 was selected. For each instrument, the responsible principal investigator was asked to complete a short form concerning its cost, age, funding sources, condition, principal field of research use, and other characteristics.

Supersystems. The survey excluded equipment assigned to any of 18 university-administered Federally Funded R&D Centers (FFRDCs).[4] The instrumentation in these large national labs is well known to the sponsoring agencies and is outside the scope of this study. However, academic institutions also contain a number of other large, specialized research facilities that are built around or consist of a single integrated instrument system, such as a computer center, observatory, nuclear reactor, or oceanographic research vessel. Such "supersystems," which generally cost over $1 million, were not fully represented in the first two cycles of the survey. The 1989-90 survey identified and collected limited information about 119 such facilities at sampled institutions. Findings for these supersystems are included in the discussion of current inventory size, but are not included in trend analyses.

Response Rates. Response rates in this voluntary survey were extremely high. All 79 sampled colleges/universities and medical schools participated in the 1989-90 survey. Usable questionnaire responses were obtained for all supersystems, for 92 percent of sampled departments/centers, and for 90 percent of sampled instruments, continuing the high levels of participation established in earlier cycles of the survey.

Estimates. All findings discussed in this report are in the form of national estimates developed from the study samples. As well as reflecting original probabilities of selection, for institutions, departments, and instruments the estimates contain statistical adjustments for questionnaire nonresponse and imputations for item nonresponse within questionnaires to ensure that reported estimates fully represent all intended institutions, fields, and instruments.

Sampling Errors. Since they are based on samples, the estimates presented in this report are subject to variability due to sampling error. For example, most overall estimates (not broken out by field) have sampling errors (coefficients of variation) of 2-6 percent, which implies a 95 percent confidence interval of about twice that magnitude; i.e., plus or minus 4-12 percent of the reported estimate. Estimates for the smaller fields, such as the agricultural or computer sciences, have sampling errors 2-3 times larger than those for all fields combined.

Reference Periods. In all three surveys, information about current equipment needs and priorities was obtained with reference to the actual survey year (i.e., 1983, 1986, and 1989 for the physical and computer sciences and engineering--Phase I; 1984, 1987, and 1990 for the agricultural, biological, and environmental sciences--Phase II). Information about equipment dollar amounts and expenditures refers to the year preceding the survey (i.e., 1982, 1985, and 1988 for the Phase I fields; 1983, 1986, and 1989 for the Phase II fields).

Inflation Adjustment. Throughout this report, there are many references to percent change in equipment expenditures and investments from 1985-86 to 1988-89. All such percent change figures for dollar amounts are adjusted for inflation on the basis of U.S. Bureau of Labor Statistics Producer Price Indices for equipment-related products. Actual dollar amounts given are not adjusted for inflation.

Additional Information. Additional information about the study design, procedures, questionnaires, response rates, sampling errors, and other aspects of the survey methodology is contained in a separate *Technical Notes* report. All findings from the 1986-87 and 1989-90 surveys cited in this report are derived from a larger series of tabulations, which are presented in a separate *Detailed Analysis Tables* report. Where comparable data from the 1983-84 baseline survey are available, 6-year trends are also described. All data cited from the 1983-84 survey are taken from the report *Academic Research Equipment in Selected Science/Engineering Fields* (National Science Foundation, June 1988, SRS 88-D1).[5] These reports are available from the National Science Foundation.[6]

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[4]The 18 excluded FFRDCs are listed in Appendix B.

[5]That report also cites findings for the 1986-87 survey, which differ slightly from statistics shown in the current report as a result of imputations and other minor statistical adjustments made since the earlier report was published. Where such differences exist, the current report should be considered authoritative.

[6]Contact Dr. Eileen Collins, (202) 634-4655.

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RESULTS

Annual Expenditures

Equipment Purchases. Annual expenditures for purchase of academic research equipment in major science/engineering fields showed an upward trend during the 1980s. After increasing from $400 million in 1982-83 to $678 million in 1985-86, equipment purchases grew to $831 million in 1988-89 (Table 1).[7] The latter change represents a real (inflation-adjusted) increase of 11 percent over the 3-year period between the two surveys.

Table 1. Trends in annual expenditures for academic research equipment, 1982-83 to 1988-89

Type of expenditure and field	Survey		
	1982-83	1985-86	1988-89
	(Dollars in millions)		
Purchase of nonexpendable research equipment costing $500+, total	400	678	831
Engineering	96	174	253
Agricultural sciences	28	34	46
Biological sciences	132	194	246
Chemistry	39	81	84
Computer science	20	49	45
Environmental sciences	33	55	55
Physics/astronomy	52	91	102
Maintenance/repair of existing research equipment, total	101	149	175
Service contracts and field service	*	72	87
Other (salaries, tools, etc.)	*	77	87
Operation of existing research equipment (supplies, technician salaries, etc.), total	*	*	403

*Not ascertained in that survey.

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

SOURCE: National Science Foundation, SRS

Most major science/engineering fields evidenced substantial increases in annual equipment purchases from 1982-83 to 1985-86, but spending changes from 1985-86 to 1988-89 were more uneven. Of the seven major fields studied, engineering had the largest real increase in equipment purchases over this period (34 percent), and the agricultural and biological sciences also showed notable spending increases (21 percent and 14 percent, respectively). Equipment spending levels in chemistry and physics/astronomy were essentially the same in 1988-89 as in 1985-86, and the computer and environmental sciences both evidenced real-dollar spending cutbacks (-14 percent and -23 percent, respectively).

Although dollar amounts of equipment purchases varied considerably, the proportion of total academic R&D expenditures that were devoted to equipment purchases remained generally stable over the period encompassed by this research. Equipment purchases represented 10 percent of total R&D spending in 1988-89 and about 9 percent in 1982-83 (Table 2). Overall, and in most individual fields, equipment spending in 1985-86 represented a somewhat higher fraction of total R&D (11 percent, overall) than occurred in either the preceding or subsequent period.

Table 2. Expenditures for purchase of academic research equipment as a percentage of total R&D expenditures, by field, 1982-83 to 1988-89

Type of expenditure and field	Percent of total R&D for purchase of research equipment*		
	1982-83	1985-86	1988-89
Total	9	11	10
Engineering	9	12	12
Agricultural sciences	3	3	4
Biological sciences	10	11	10
Chemistry	13	19	15
Computer science	13	17	11
Environmental sciences	6	8	6
Physics/astronomy	12	14	12

*Total R&D expenditures for 1982, 1985, and 1988 were obtained from *Academic Science/Engineering: R&D Funds, Fiscal Year 1988*, National Science Foundation, NSF 89-326, p. 17.

SOURCE: National Science Foundation, SRS

While the patterns were generally stable over time within individual fields, the seven major science/engineering fields consistently differed from one another in the proportion of total R&D spending devoted to equipment purchases. On this measure of equipment intensiveness, the agricultural, biological, and environmental sciences were consistently lower than the physical sciences and engineering (Table 2).

[7]These data refer to purchases of nonexpendable research equipment costing $500 or more per unit.

Indirect Equipment Costs. In addition to their direct expenditures for equipment purchases, institutions also spent $175 million for maintenance/repair of research equipment and $403 million for equipment operation in 1988-89 (Table 1). These spending levels mean that, for every dollar spent to purchase new research equipment in 1988-89, institutions spent an additional 69 cents to operate, maintain, and repair their existing research equipment. Relative to their levels of equipment purchases, 1988-89 expenditures for equipment maintenance and repair were especially high in computer science (which relies heavily on service contracts for equipment maintenance), and expenditures for equipment operation were especially high in the agricultural sciences (Table 3).

Table 3. Annual expenditures for maintenance/repair and operation of existing academic research equipment per dollar of annual expenditures for purchase of additional research equipment, by field, 1988-89

Field	Equipment maintenance/repair	Equipment operation
Total	$.21	$.48
Engineering	.15	.35
Agricultural sciences	.26	1.05
Biological sciences	.23	.53
Chemistry	.21	.28
Computer science	.37	.33
Environmental sciences	.28	.67
Physics/astronomy	.19	.58

SOURCE: National Science Foundation, SRS

Inventory Size and Composition

Current Inventory. About 80,000 instrument systems in the $10,000 and over range were being used for science/engineering research in academic settings in 1988-89 (Table 4). The aggregate purchase price of these instruments was about $5 billion.

Nearly all of these instruments (99.6 percent) were in the $10,000 to $999,999 price range. However, the approximately 350 systems that cost $1 million or more collectively accounted for a significant share of the total investment: $1.8 billion (36 percent). Mainframe computers and their associated peripherals in computer centers constituted the bulk of these high-cost systems.

Table 4. Aggregate amount of academic research equipment costing $10,000 or more per system, by system price range and location, 1988-89

System price range	Number of systems	Aggregate purchase price of moveable research equipment	
		Amount	Percent
		(Dollars in millions)	
Total	79,300	$4,961.4	100%
Systems costing $10,000-$999,999	78,950	3,177.3	64
In academic departments	65,700	2,624.1	53
In nondepartmental research centers	13,250	553.2	11
Systems costing $1 million or more	350	1,784.1	36
In academic departments	50	103.7	2
In nondepartmental research centers	20	51.9	1
"Supersystems," total	290	1,628.5	33
Computer centers	190	1,309.9*	26
Research vessels	20	134.5**	3
Nuclear science facilities	20	67.9	1
Observatories	40	53.7	1
Other	30	62.5	1

*Entry indicates purchase cost of all computing equipment in the facility.

**Entry indicates cost of entire vessel and its associated research equipment.

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

SOURCE: National Science Foundation, SRS.

Almost all of the colleges/universities represented in the survey, and several of the medical schools, had at least one such computer center; the aggregate purchase price of the computing equipment in these centers was approximately $1.3 billion. Large research vessels, nuclear science facilities (large reactors, cyclotrons, electron storage rings, etc.), observatories, and other systems costing $1 million and over accounted for an additional 10 percent of the total inventory investment.

Of the $3.2 billion of science/engineering research equipment in the $10,000 to $999,999 range, most was located in traditional academic departments (Table 4). However, about one in every six such systems, representing a similar proportion of the dollar investment, were located in specialized research centers outside the institution's department structure.

By field, the 1988-89 stock of research instrumentation in the $10,000 to $999,999 range was most heavily concentrated in the biological sciences, which had 29 percent of aggregate investment; engineering, 26 percent; chemistry, 17 percent; and physics/astronomy, 11 percent (Table 5). The agricultural (3 percent), computer (5 percent), and environmental (8 percent) sciences, collectively accounted for the remaining aggregate investment.

Table 5. Aggregate amount of academic research equipment in $10,000-$999,999 range, by field, 1988-89

Field	Number of systems	Aggregate purchase price	
		Amount	Percent
		(Dollars in millions)	
Total	78,950	$3,177.3	100%
Engineering	18,900	838.8	26
Agricultural sciences	3,850	93.3	3
Biological sciences	29,530	928.0	29
Chemistry	10,360	551.0	17
Computer science	3,700	164.6	5
Environmental sciences	4,480	246.3	8
Physics/astronomy	8,130	357.3	11

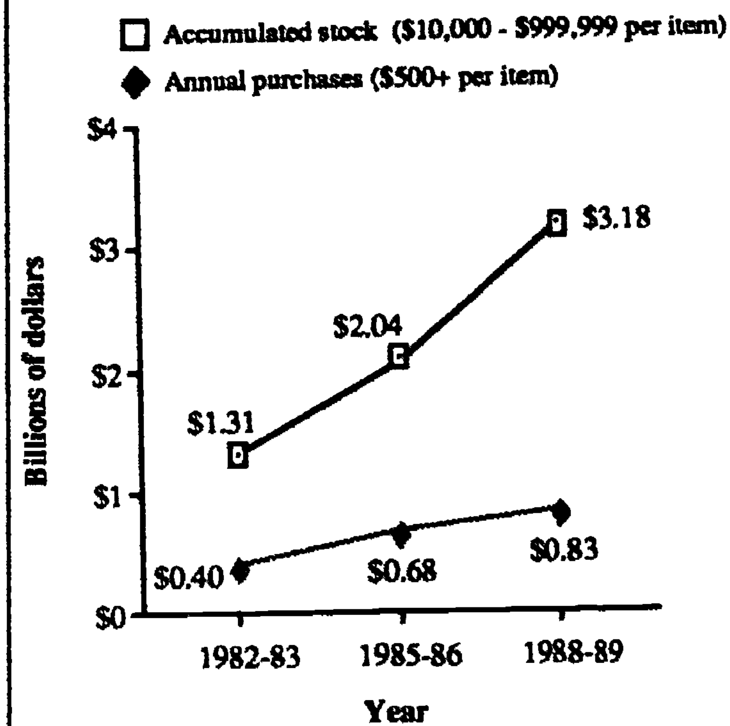
NOTE: Details may not sum to totals due to rounding.

SOURCE: National Science Foundation, SRS.

Trends in Inventory Size. The accumulated national stock of academic research equipment in the $10,000 to $999,999 price range grew substantially over the period encompassed by this survey series: from $1.3 billion in 1982-83 to $2.0 billion in 1985-86 to $3.2 billion in 1988-89 (Figure 1). The latter change represents a real (inflation-adjusted) net increase of 51 percent over the 3-year period following the second survey, continuing the high rate of inventory growth seen earlier from 1982-83 to 1985-86.

In relative terms, computer science had the greatest net expansion in its stock of research equipment, the (non-inflation-adjusted) aggregate purchase price of which trebled from 1982-83 ($50 million) to 1988-89 ($165 million; Table 6). Even for physics/astronomy, which had the lowest overall increase during this period, (nonadjusted) instrumentation dollar amounts nearly doubled, from $180 million in 1982-83 to $357 million in 1988-89.

Figure 1. Trends in annual purchases and accumulated stock of academic research equipment, 1982-89



Source: National Science Foundation, SRS

Table 6. Aggregate purchase price of academic research equipment in $10,000 to $999,999 range, by field, 1982-83 to 1988-89

Field	1982-83	1985-86	1988-89
	(Dollars in millions)		
Total	1,303	$2,044	$3,177
Engineering	296	467	837
Agricultural sciences	38	82	93
Biological sciences	420	645	928
Chemistry	50	109	165
Computer science	210	340	551
Environmental sciences	109	172	246
Physics/astronomy	180	248	357

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

SOURCE: National Science Foundation, SRS.

During the 3-year period since the last survey, engineering had the greatest net real expansion in its instrumentation stocks, which increased by 74 percent, from $467 million in 1985-86 to $837 million in 1988-89 (Table 6). Chemistry also had a substantial rate of inventory growth during this period (59 percent), from $340 million in 1985-86 to $551 million in 1988-89. The environmental sciences had the lowest rate of real inventory expansion (26 percent), growing from $172 million in 1985-86 to $246 million in 1988-89. The remaining fields (the agricultural, biological, and computer sciences, and physics/astronomy) all had inventory growth rates in the 40-47 percent range.

Computer Center Trends. In general, trends in instrument systems costing $1 million or more cannot be addressed in this report, since the 1989-90 survey was the first to include all such systems. Academic computer centers are the one "supersystem" category for which reliable trend information is available from all three surveys. The aggregate amount of computing equipment in such centers grew dramatically during the 3-year period 1982-83 to 1985-86, more than doubling from $423 million to $877 million. The subsequent 3-year period saw continued net growth to $1.3 billion. However, the overall growth from 1985-86 to 1988-89 was at a comparatively low rate (37 percent after adjustment for inflation), and it was largely due to the establishment of a few large supercomputer centers during this period, rather than to a widespread upgrading or expansion of centralized computer facilities.[8]

Turnover Rates. The change figures cited above indicate net change in equipment inventories. They reflect the combined effects of inventory additions and deletions during the periods between surveys, as new research instruments are acquired and older, obsolete instruments are retired.

Overall, about two-fifths (38 percent) of the instruments in science/engineering research use in 1988-89 had been acquired within the previous 3 years, and about one-fourth of the instruments that were 3 or more years old at the time of the last survey had been retired by 1988-89 (Table 7).

Table 7. Rates of acquisition and retirement of academic research equipment, by field, 1985-86 to 1988-89*

Field	Acquisitions: of systems in research use in 1988-89, percent acquired since 1985-86	Retirements: of systems 3 or more years of age in 1985-86, percent retired from research use by 1988-89
Total	38%	27%
Engineering	46	25
Agricultural sciences	28	15
Biological sciences	29	28
Chemistry	40	26
Computer science	59	74
Environmental sciences	35	15
Physics/astronomy	43	32

*Estimates refer to research equipment systems costing $10,000-$999,999.

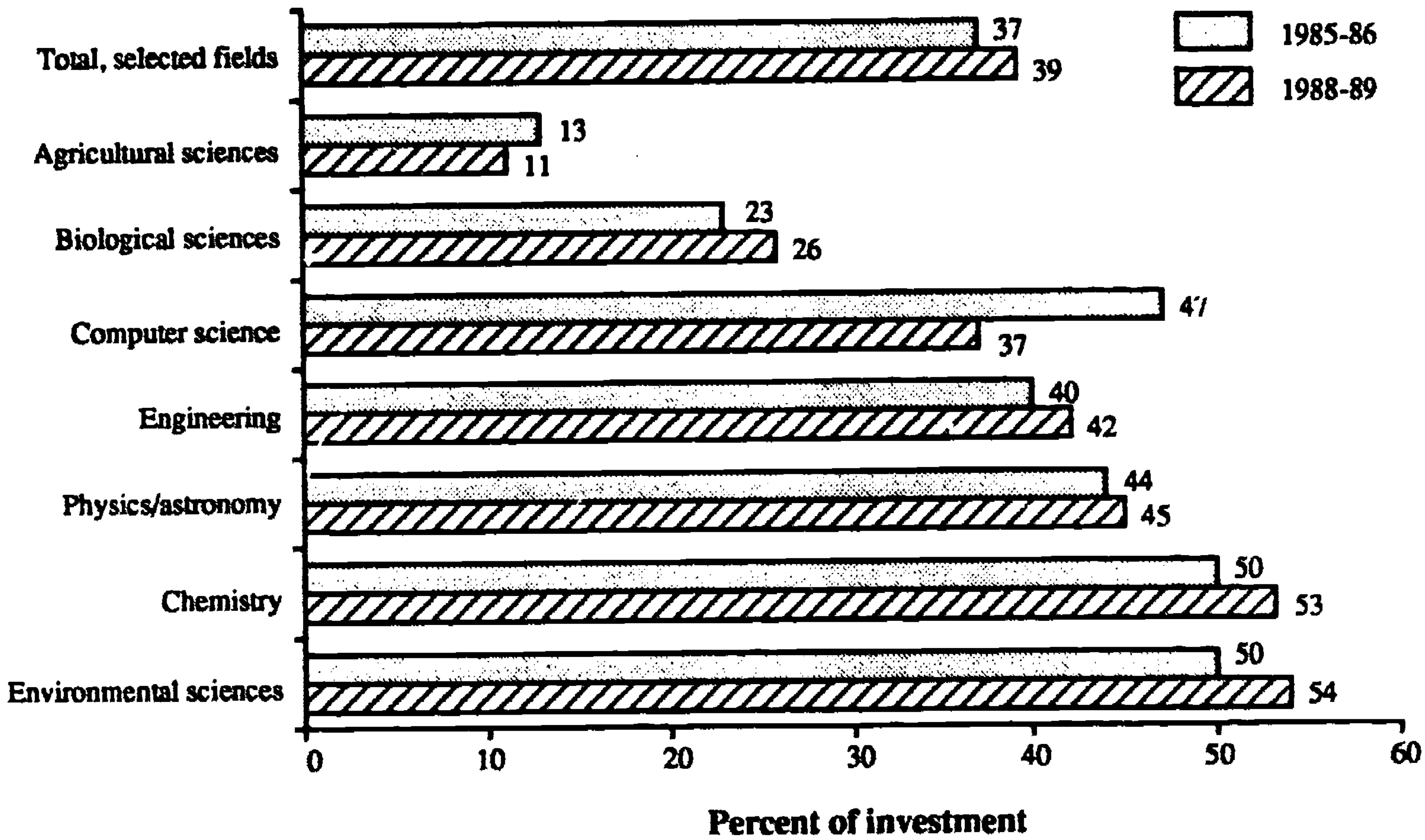
SOURCE: National Science Foundation, SRS.

Different fields showed different patterns of equipment turnover. Computer science had the highest rate of equipment acquisitions since the last survey, with 59 percent of its 1988-89 instrument systems having been acquired in the prior 3 years (Table 7). The comparatively modest net increase in computer science's equipment inventory, noted earlier, was due to the fact that this field also had a very high rate of retirement of older equipment during the same period: of the instrument systems that were 3 or more years old at the time of the last survey, 74 percent had been retired by 1988-89. Physics/astronomy evidenced a similar pattern, achieving a modest net increase in equipment stocks during the 3-year period between the last two surveys by having much turnover within the period, with acquisition and retirement rates of 43 percent and 32 percent, respectively.

The agricultural sciences had the same net inventory change as computer science (both increased by 46-47 percent), but they got to that place by a very different route: they had the lowest rate of equipment acquisitions of the seven major fields (28 percent), but also the lowest rate of retirement of older equipment (15 percent). Engineering and chemistry, which both had large net increases in equipment stocks, had high rates of acquisition of new equipment (40-46 percent) accompanied by only moderate rates of retirement of older equipment (25-26 percent).

[8]For additional information about trends in academic computer centers, see *Academic Research Equipment in Computer Science, Central Computer Facilities and Engineering: 1989*, National Science Foundation, 1991, NSF 91-304).

Figure 2. Proportion of total investment in $10,000 - $999,999 academic research equipment that is for systems costing $100,000 or more, by field, 1985-86 to 1988-89



Source: National Science Foundation, SRS

Big Ticket Items. Even when "supersystems" and other instrument systems costing $1 million or more are excluded, big ticket items costing $100,000 to $999,999 constituted a substantial 39 percent share of the total investment represented by the 1988-89 inventory. The prominence of these big ticket items varies considerably from field to field, ranging from a low of 11 percent of total equipment investment in the agricultural sciences to highs of 53 and 54 percent in chemistry and the environmental sciences (Figure 2). Somewhat surprisingly, however, the prominence of big ticket items did not change much after the 1985-86 survey. Most fields showed increases of less than 5 percentage points in the share of total equipment investment represented by such instruments. The only field to show a change larger than that was computer science, where systems costing $100,000 or more actually declined in prominence, dropping from 47 percent of the total investment in 1985-86 to 37 percent in 1988-89. This may reflect a general trend toward downsizing and decentralization of academic computing equipment, as PCs, networks, and minicomputer systems become increasingly prevalent, supplanting the large mainframes.

Sources of Funds

Overall Trends. During the 1980s, Federal and non-Federal sources made roughly the same total contributions to the funding of the nation's growing stock of academic research equipment, although the Federal share declined, from slightly more than half of the total in 1982-83 to somewhat less than half in 1985-86 and 1988-89 (Figure 3).[9]

The largest contributor of Federal funds for academic research equipment continued to be NSF (Figure 4). Recently, however, NIH (the second largest Federal contributor) narrowed the gap, increasing from 76 percent of NSF's contribution in 1982-83 to 93 percent in 1988-89. The Department of Defense also became an increasingly prominent source of equipment funds, with its accumulated contribution increasing from $153 million in 1985-86 to $302 million in 1988-89.

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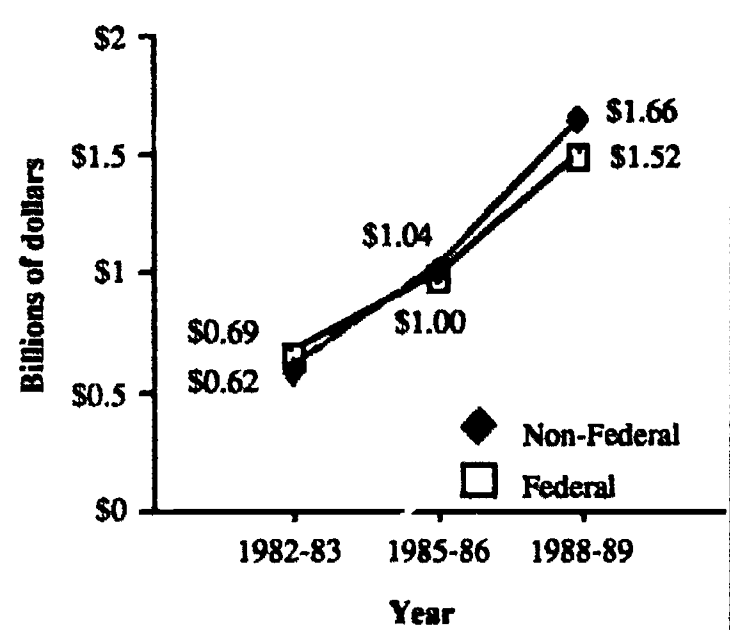
[9]All of the data in this section refer to equipment in the $10,000 to $999,999 price range.

Figure 3. Federal and non-Federal funding shares of national stock of academic research equipment, 1982-83 to 1988-89



Source: National Science Foundation, SRS

Among non-Federal sources, appropriations from state governments became increasingly prominent, growing from an aggregate of $125 million in 1985-86 to $347 million in 1988-89 (Figure 4). However, institutional funding continued to be by far the largest non-Federal source of support for academic research equipment (contributing $973 million of the 1988-89 total), exceeding all individual Federal sources as well.

Although cumulative dollar amounts of instrumentation support increased from all funding sources, the overall distribution of support among sources was remarkably stable from 1982-83 to 1988-89 (Table 8). The only consistent changes over this period were for NSF, which declined from 18 to 15 percent of the total, and state government, which increased its share of the total from 5 to 9 percent.

Field Differences. Patterns of instrumentation funding support differed considerably by field (Table 9). As one would expect, NIH was the largest single funding source for research equipment in the biological sciences. Similarly, the environmental sciences, physics/astronomy, and the agricultural sciences all obtained substantial funding from "other" Federal sources (which included NASA and the Department of Agriculture), and private/industry sources made substantial equipment contributions in computer science and engineering.

Table 8. Sources of funds for acquisition of academic research equipment, 1982-89*

Source of funds	1982-83	1985-86	1988-89
	(Dollars in millions)		
Total (aggregate purchase price)	$1,311	$2,044	$3,177
	(Percent of total)		
Federal, total	53	49	48
NSF	18	17	15
NIH	14	14	14
Department of Defense	8	7	10
Department of Energy	5	5	4
Other (NASA, USDA, etc.)	7	5	4
Non-Federal, total	47	51	52
Institution funds	30	30	31
State government	5	6	9
Private/industry	11	12	11
Other	2	2	1

*Base = aggregate purchase price of all instrument systems costing $10,000-$999,999 that were in research use during the specified year.

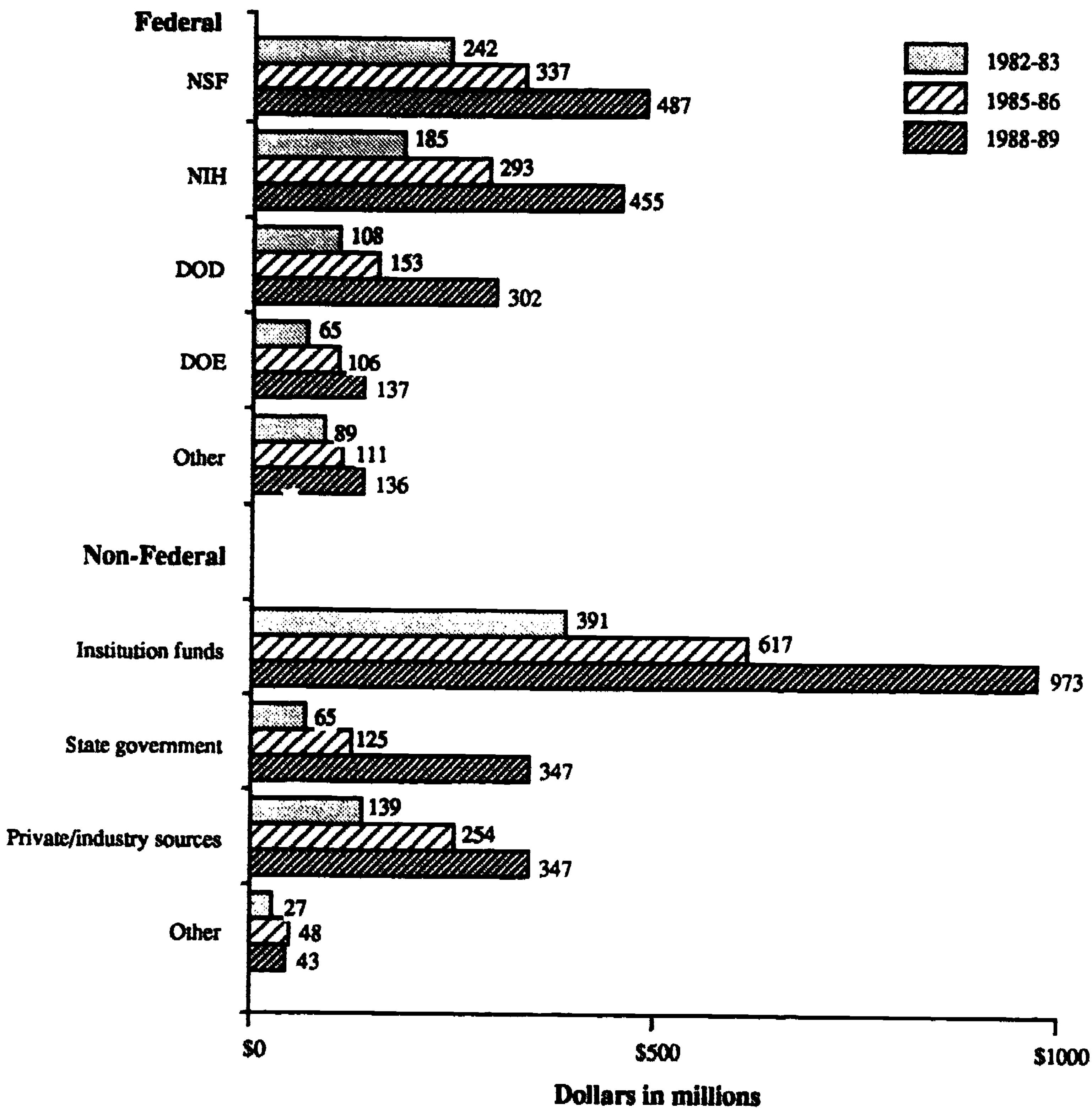
NOTE: Details may not sum to totals due to rounding.

SOURCE: National Science Foundation, SRS.

Most fields experienced fairly stable equipment funding patterns over the period encompassed by this survey (Table 9). This was especially true for the agricultural and biological sciences, where the funding mix for the 1989 equipment stock was almost identical to the one found 6 years earlier. Physics/astronomy and engineering evidenced the largest funding shifts over this period. In physics/astronomy, a substantial decline in Federal instrumentation support (principally from NASA and NSF) was offset by increased support from institutional funds and from state governments. Engineering experienced a similar decline in Federal support (from all of its major sources) and had offsetting increases from state governments and private/industrial sources.

Institution Control. The increased involvement of state governments in funding academic research equipment primarily benefitted public institutions, which obtained 13 percent of the funding for their 1988-89

Figure 4. Contributions to aggregate amount of academic research equipment, by source of funds, 1982-83 to 1988-89



Source: National Science Foundation, SRS

Table 9. Sources of funds for acquisition of academic research equipment in selected science/engineering fields, 1982-89*

Source of funds	Engineering		Agricultural sciences		Biological sciences		Chemistry		Computer science		Environmental sciences		Physics/astronomy	
	1982	1988	1983	1989	1983	1989	1982	1988	1982	1988	1983	1989	1982	1985
	(Dollars in millions)													
Total (aggregate purchase price)	$296	$816	$38	$91	$420	$906	$211	$540	$50	$160	$109	$217	$180	$348
	(Percent of total)													
Federal, total	48	37	22	23	51	52	54	51	44	42	47	48	78	64
NSF	17	13	5	5	9	8	34	25	22	17	15	20	29	25
NIH	1	1	4	4	38	39	9	14	1	1	<1	<1	1	<1
DOD	19	16	<1	1	1	3	5	6	19	22	6	5	13	13
DOE	6	4	1	2	1	<1	3	4	1	1	8	6	16	16
Other	5	3	13	10	2	2	3	1	2	1	17	17	17	10
Non-Federal, total	52	63	78	77	49	48	46	49	56	58	53	52	24	36
Institution funds	30	27	49	46	34	[illegible]	35	38	23	24	26	28	14	27
State government	6	15	18	18	5	[illegible]	3	6	10	3	7	10	<1	4
Private/industry	14	19	9	12	8	7	7	5	23	29	18	12	7	4
Other	2	2	3	1	3	1	1	1	1	2	2	2	2	1

*Base = aggregate purchase price of all instrument systems costing $10,000-$999,999 that were in research use during the specified year.

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

SOURCE: National Science Foundation, SRS.

instrumentation from this source (Figure 5). The relative decline in Federal support also differentially benefitted public institutions, which are less dependent on Federal support than are private institutions. Over the 3-year period since the 1985-86 survey, the combination of these two factors produced a larger overall inventory increase for public institutions (from $1.4 billion to $2.2 billion, a real increase of 53 percent) than for private institutions (from $0.6 billion to $1.0 billion, a 45 percent real increase).

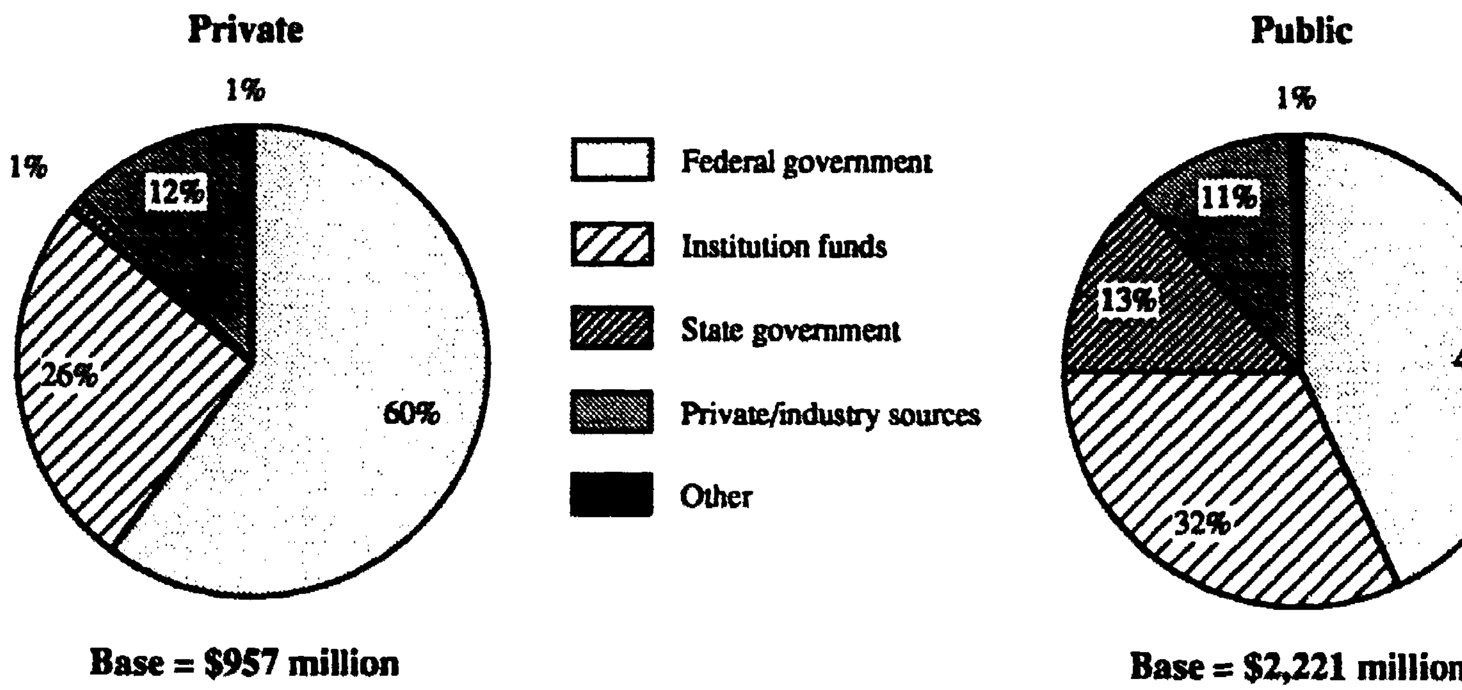
Department Needs and Assessments

Need for Big Ticket Equipment. In all three cycles of the survey, department heads were asked to identify the cost range for which increased Federal instrumentation support would be most beneficial to research investigators in their units. The overall percentage identifying equipment systems in the $50,000 and over range as being most needed progressively increased, from 26 percent in 1983-84 to 35 percent in 1986-87 to 46 percent in 1989-90 (Figure 6). Particularly in the last 3 years, increased need for such big ticket equipment was especially pronounced in engineering, computer science, and physics/astronomy. Department heads in the agricultural and biological sciences showed lesser interest in such high-cost equipment, with the majority of them continuing to urge increased Federal support for equipment in the $10,000 to $50,000 range.

Reasons for Needing New Equipment. In the most recent survey, department heads were asked to identify up to three items of research equipment that were currently the topmost priorities for their units; they were also asked to indicate the instrument's approximate cost and the reason it was needed. The types of equipment identified as being most needed are discussed in the next section. As for the costs and reasons associated with departments' future equipment needs, two things are striking (Table 10):

- In all but two fields, the median prices of departments' topmost equipment priorities were in the six-figure range, reiterating the growing importance of big ticket items. The exceptions again were the agricultural sciences, where the median price was $35,000, and the biological sciences, with a median price of $50,000.

Figure 5. Source of funds for acquisition of academic research equipment in selected science/engineering fields, by institution control, 1988-89*



* Base = aggregate purchase price of research equipment costing $10,000 - $999,999 per system.
Source: National Science Foundation, SRS

Table 10. Cost and intended use of departments' top-priority research equipment needs*, by field, 1989-90

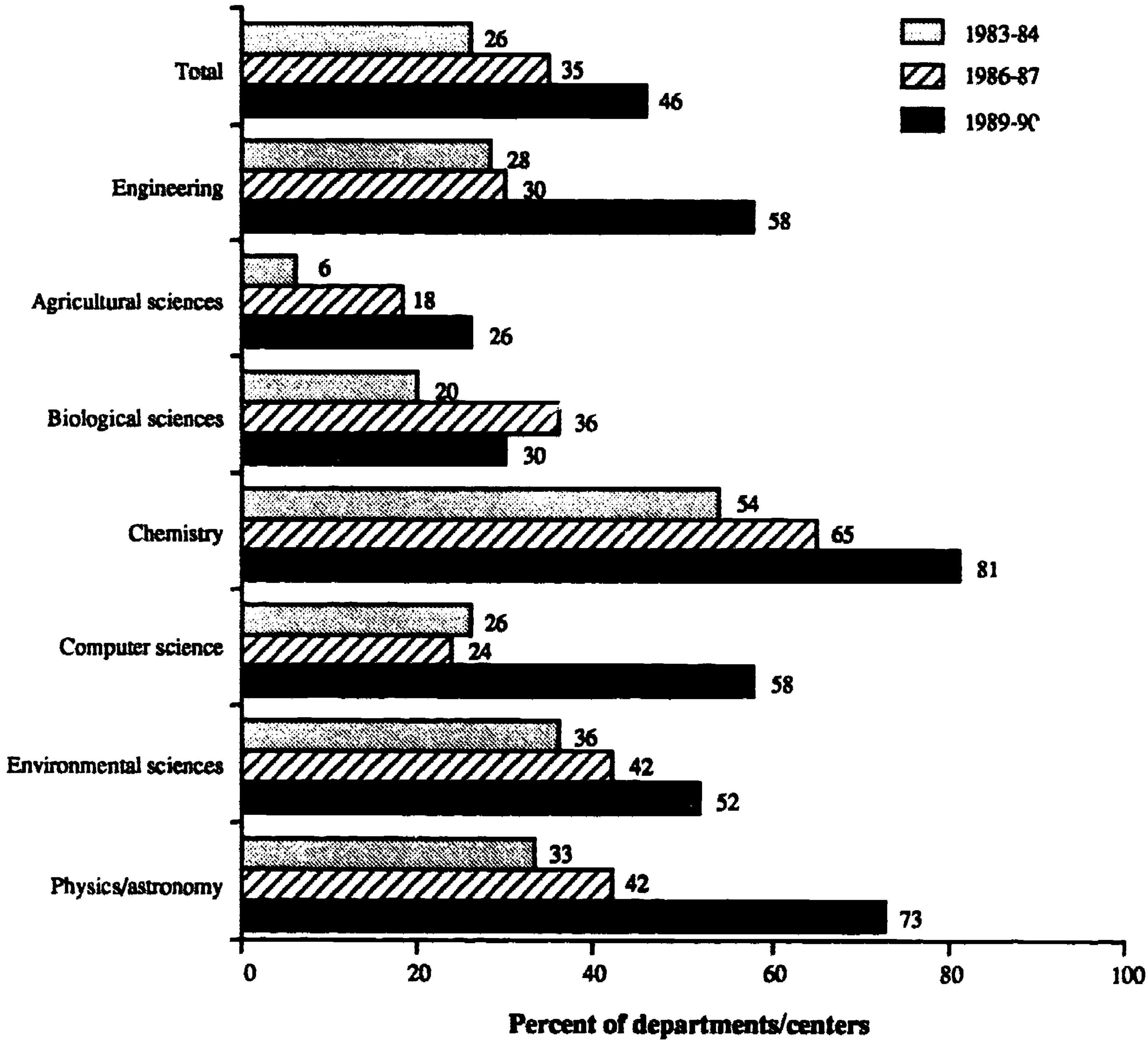
Field	Median price	Intended use: Total	Replace an existing instrument	Expand capacity (more copies of existing equipment)	Upgrade capabilities (to perform experiments you cannot do now)
		(Percent of aggregate price of all reported needs)			
Total	$80,000	100	17	25	58
Engineering	100,000	100	13	30	57
Agricultural sciences	35,000	100	15	32	54
Biological sciences	50,000	100	18	28	54
Chemistry	150,000	100	17	21	62
Computer science	200,000	100	18	26	56
Environmental sciences	100,000	100	27	17	56
Physics/astronomy	200,000	100	13	11	76

*From lists of three items per department/center of top-priority research instruments in $10,000-$1 million range. Needs lists include some items over $1 million and some that call for multiple copies (e.g., 10 workstations-$250,000).

NOTE: Percentages may not sum to 100 due to rounding.

SOURCE: National Science Foundation, SRS.

Figure 6. Percent of department/center heads identifying equipment in the $50,000 and above cost range as being the area where increased Federal funding support would be most beneficial, by field, 1983-90



NOTE: Percentages may not sum to 100 due to rounding.
Source: National Science Foundation, SRS

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- In all seven fields, over half of all top-priority instrument systems were needed to "upgrade capabilities, i.e., to perform experiments you cannot do now." In other words, the mix of needs for new research equipment was dominated by departments' needs to stay abreast of emerging technologies (overall, 58 percent of all top priority needs are in this category), rather than by a need to replace obsolete or worn-out equipment (17 percent of the total) or a desire to expand a research program by obtaining additional copies of existing equipment (25 percent). This emphasis on new technologies ("upgrade capabilities") was especially pronounced in the physical sciences, physics/astronomy (76 percent of the top-priority needs) and chemistry (62 percent).

Perceived Trends in Funding Support. The changes in aggregate dollar amounts of instrumentation funding support between the 1986-87 and 1989-90 surveys, as discussed above, were not evenly distributed across all departments in a given field. For any particular funding source, some departments experienced funding increases over the 3 years before the current survey, while others saw their funding remain the same or even decline. Overall, for each of the three major funding sources (Federal, state, and institution), about half of all science/engineering department heads reported that instrumentation funding remained about the same (or was not applicable because the department had received no funds from the source in any of the 3 years prior to the survey), with the other half being evenly split between departments that received increased instrumentation funding and those with funding decreases (Table 11).

Table 11. Perceived trends in the past 3 years in funding support for academic research equipment in selected science/engineering fields, 1989-90

Funding source and perceived trend in the past 3 years	Total	Engineering	Agricultural sciences	Biological sciences	Chemistry	Computer science	Environmental sciences	Physics/ astronomy
	(Percent of departments/centers)							
Federal government	100	100	100	100	100	100	100	100
Increased	24	20	12	26	48	35	27	24
Remained the same	51	52	63	51	36	43	46	43
Decreased	25	28	25	23	16	22	27	33
State government*	100	100	100	100	100	100	100	100
Increased	20	28	20	12	23	26	29	18
Remained the same/NA	60	53	43	70	53	55	56	71
Decreased	20	19	37	18	24	19	15	11
Institution funds	100	100	100	100	100	100	100	100
Increased	24	29	19	18	36	28	28	29
Remained the same/NA	55	50	53	62	49	48	47	52
Decreased	21	21	28	20	16	24	25	19
Private foundations/ organizations	100	100	100	100	100	100	100	100
Increased	13	15	25	10	7	6	15	5
Remained the same/NA	79	78	65	85	79	88	68	90
Decreased	8	7	10	5	14	6	17	5
Business/industry	100	100	100	100	100	100	100	100
Increased	19	29	25	9	24	33	21	9
Remained the same/NA	73	62	66	86	61	48	71	84
Decreased	8	9	9	5	15	19	8	7

*Categories refer to state equipment appropriations and equipment funded as part of state capital projects.

NOTE: Percentages may not sum to 100 due to rounding.

SOURCE: National Science Foundation, SRS.

For the remaining sources (private foundations/organizations and business/industry sources), most departments reported no significant change during the past 3-year period (79 percent and 73 percent, respectively). However, in most fields, among the departments that did report funding changes from these latter sources, funding increases were more common than funding decreases.

Chemistry had the most widespread increases in Federal support, with 48 percent of department heads reporting increased support and only 16 percent reporting decreases. Computer science also had more departments with increased Federal support (35 percent) than with decreased support (22 percent). In several other fields, however, declines in Federal funding support were actually more common than increases: the agricultural sciences (25 percent down, 12 percent up), engineering (28 percent down, 20 percent up), and physics/astronomy (33 percent down, 24 percent up).

Other Perceived Trends. Nearly all science/engineering department heads reported that their instrumentation needs had grown during the 3-year period (Figure 7). Similarly, although relatively few department heads reported significant equipment funding increases from any one source, most (69 percent) indicated that the overall dollar value of their research equipment had increased, and only 4 percent said it had decreased.

Perhaps the most positive finding from the department survey is that, despite the near-universal perception that instrumentation needs increased over the 3-year period before the 1989-90 survey, only 17 percent of science/engineering department heads reported a decline in the overall adequacy of the research equipment in their units; about one-third said the overall adequacy had remained the same (i.e., that their instrumentation had more or less kept pace with their changing needs), and fully half (50 percent) acknowledged that the adequacy of their instrumentation had improved during this period.

As with most other equipment trend indicators, different views about recent equipment trends were found in the different fields. One exception to this general rule was that, on the question of changes in instrumentation needs, nearly all department heads in all science/engineering fields agreed that the needs increased significantly in the 3 years since the last survey (Table 12).

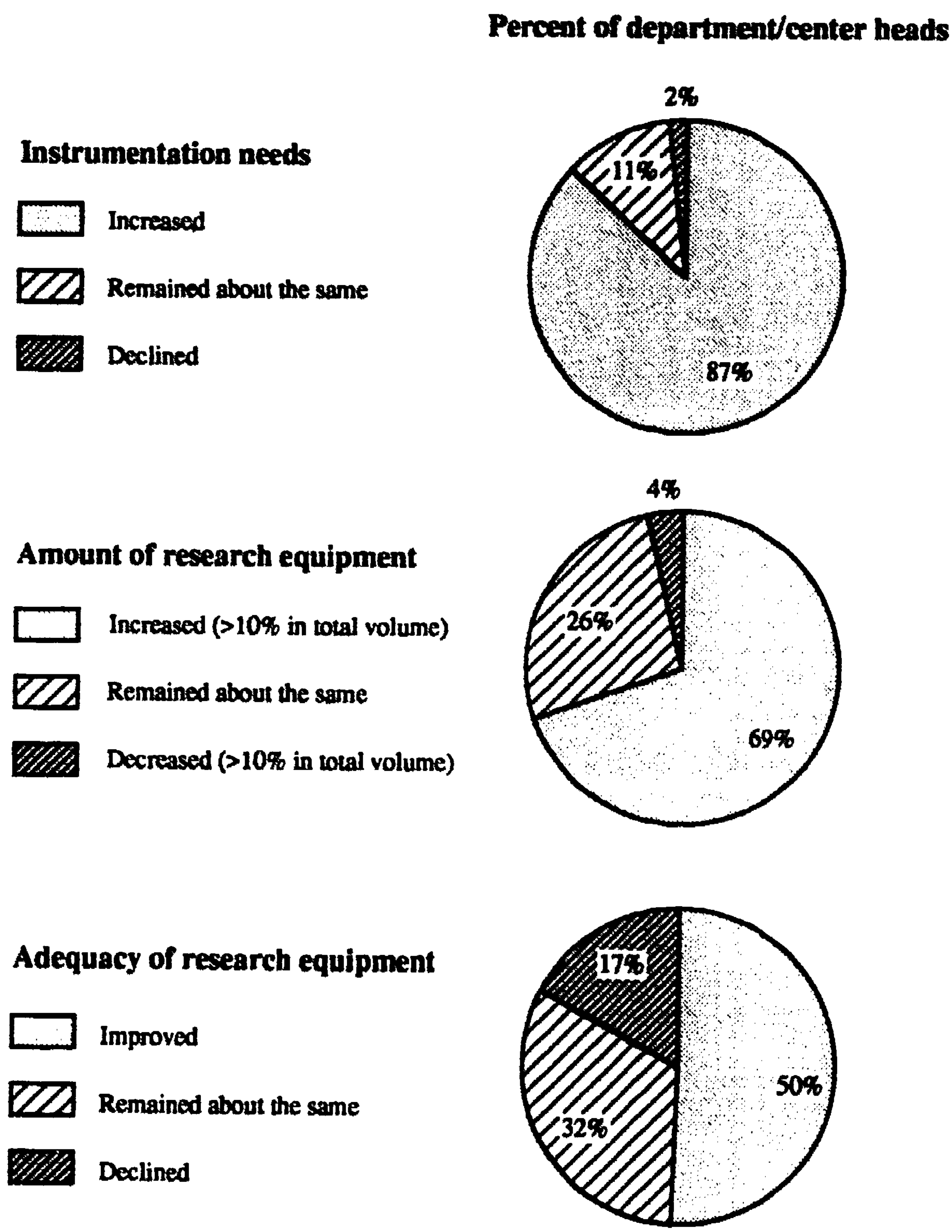
On the other two assessment measures, department heads in chemistry were the most likely to report increases in equipment amounts (84 percent) and improvements in equipment adequacy (71 percent). Computer science also had above-average percentages on these measures. At the other extreme, physics/astronomy department heads least often reported increased equipment amounts (56 percent), and they were the most likely to report overall declines in equipment adequacy (29 percent). These department perceptions are generally consistent with the previously discussed inventory change findings from the equipment survey.

There are two fields for which department perceptions do not seem entirely consistent with the equipment survey findings. First, in engineering, which had the largest overall increase in equipment stocks, the percentage of department heads reporting increased equipment amounts and increased equipment adequacy was about the same as the overall average for all science/engineering fields. One possible explanation is that the large net increases in instrumentation amounts seen in the equipment survey tended to be concentrated in a relatively few large departments, rather than being widely distributed among both the large departments and the many smaller engineering departments as well.

The other apparent anomoly is in the environmental sciences, which had the lowest net expansion in instrumentation stocks of the seven major fields over the 3-year period and had an actual decline in annual equipment purchases, but which also had an above-average percentage of department heads reporting increased equipment amounts (77 percent) and adequacy (59 percent), over roughly the same period. Two possible explanations are that: (a) the equipment increases in this field during the 3 years, while not large, were more widely distributed than in other fields, and (b) some department heads' assessments may have reflected very recent influxes of equipment, which are not yet evident in the equipment survey data.

Trends in Perceived Limitations. In the 1983-84 survey, department heads were asked whether there were any important subject areas where research investigators in their units were unable to perform critical experiments because they lacked the necessary equipment. The same question was asked 6 years later, in the 1989-90 survey, and some overall improvement was evident: the

Figure 7. Perceived trends in last 3 years in department/center research equipment, 1989-90



Source: National Science Foundation, SRS

Table 12. Perceived equipment trends in the past 3 years in selected science/engineering fields, 1989-90

Statistic	Total	Engineering	Agricultural sciences	Biological sciences	Chemistry	Computer science	Environmental sciences	Physics/astronomy
Number of departments/centers	3,450	960	330	1,260	190	150	330	230
	(Percent of departments/centers)							
THE RESEARCH INSTRUMENTATION NEEDS OF THIS UNIT HAVE:								
Increased (e.g., because of expanding staff or program or other factors)	87	81	85	89	96	85	90	87
Remained the same	11	15	14	10	4	15	9	8
Declined	2	5	1	1	0	0	1	5
THE AMOUNT OF USABLE RESEARCH EQUIPMENT IN THIS UNIT HAS:								
Increased substantially (50% or more in aggregate cost/value)	17	22	10	11	30	31	23	7
Increased (by 11-49%)	52	46	57	56	54	44	54	49
Remained the same (+/-10%)	26	28	29	28	15	17	17	38
Decreased (by 11-49%)	4	4	4	5	0	7	4	6
Decreased substantially (by 50+ %)	0	0	0	1	0	0	2	0
THE ADEQUACY OF THE RESEARCH EQUIPMENT IN THIS UNIT HAS:								
Improved	50	51	54	44	71	58	59	41
Remained the same	32	33	30	36	23	28	25	30
Declined	17	16	16	19	7	14	16	29

NOTE: Percentages may not sum to 100 due to rounding.

SOURCE: National Science Foundation, SRS.

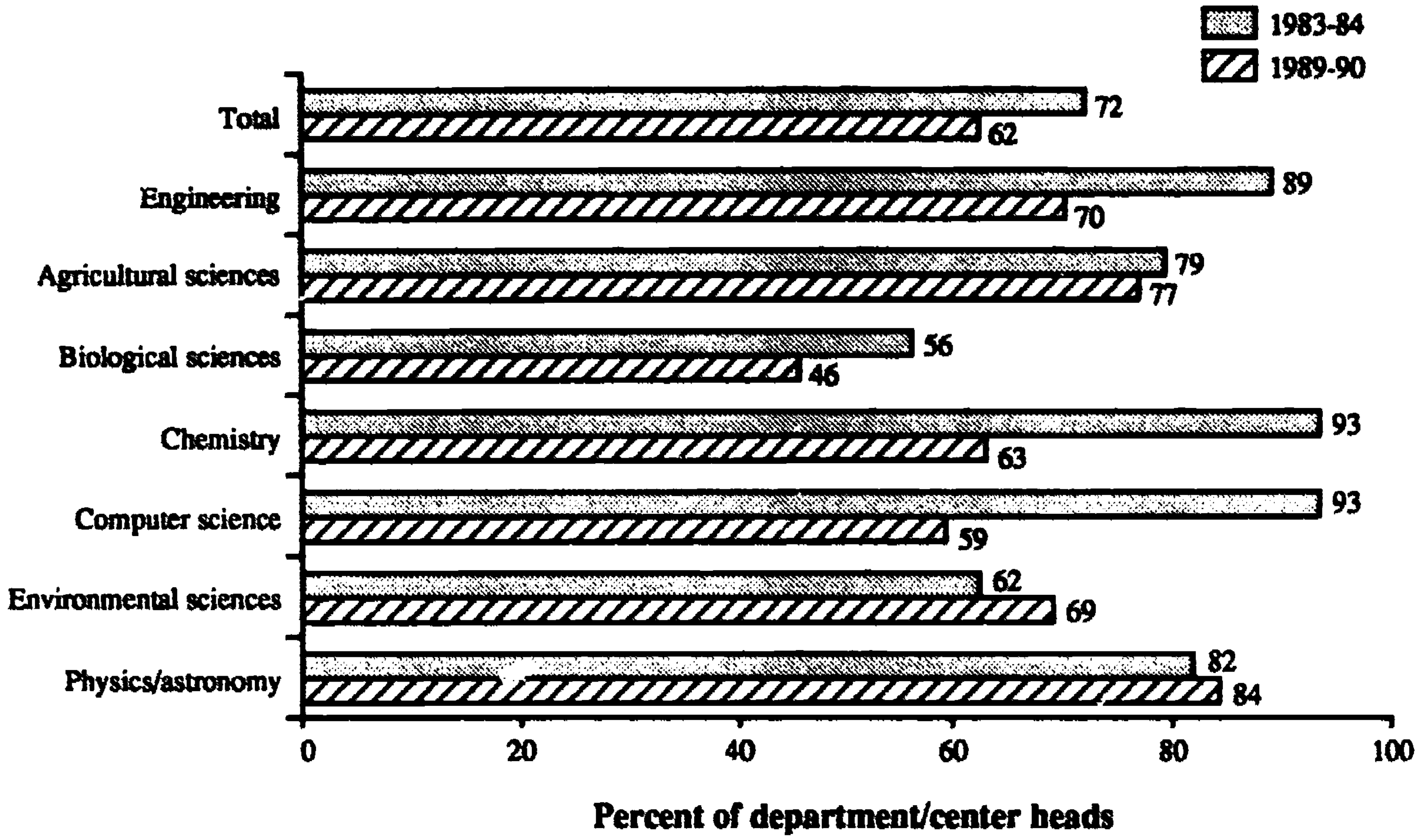
percentage of science/engineering department heads reporting such limitations declined from 72 to 62 percent (Figure 8). In some fields, the improvement was quite large, especially in computer science (from 93 percent to 59 percent), chemistry (from 93 percent to 63 percent), and engineering (from 89 percent to 70 percent).

However, in physics/astronomy and in the agricultural and environmental sciences, equipment-related limitations remained at high levels and may even have increased. It is also sobering that, despite the many quantitative and qualitative improvements that occurred over the 6-year period, the majority of the departments (i.e., over 50 percent) in almost all major science/engineering fields continued to experience impaired research productivity due to a lack of needed equipment. The one exception was the biological sciences, where the percentage of department heads complaining of this problem fell slightly below the 50 percent level (Figure 8).

Types Of Existing And Needed Equipment

A comprehensive equipment taxonomy was developed after the 1986-87 survey, with the assistance of many NSF and NIH project advisors. Existing instrument systems in the 1985-86 and 1988-89 surveys were

Figure 8. Percent of department/center heads reporting that their investigators cannot do critical experiments in their areas of research interest due to lack of needed equipment, by field, 1983-84 and 1989-90

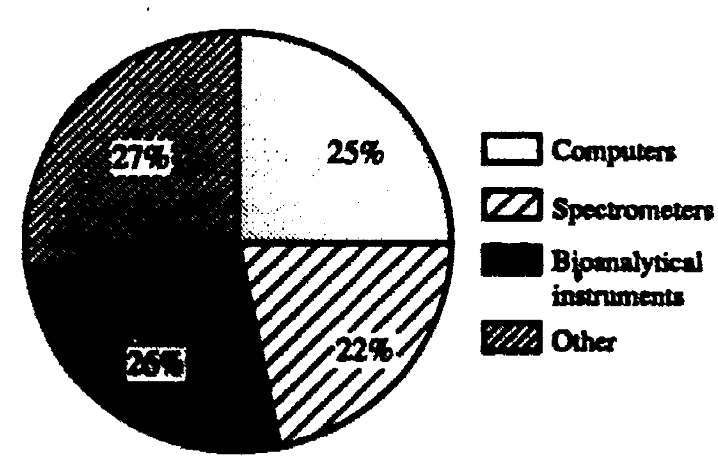


Source: National Science Foundation, SRS

classified into this taxonomy, as were the instruments department heads identified in 1989-90 as being their top-priority needs for the future. These data made it possible, for the first time, to examine the composition of current equipment inventories and trends in both existing and needed instrumentation, by type of equipment.[10]

Although the full national stock of academic research instrumentation in the $10,000 to $999,999 range is characterized by enormous diversity, there are also some conspicuous commonalities in the kinds of instruments encountered. Most equipment in the 1988-89 inventory can be classified into three broad categories of roughly equal size in terms of the investment they represent: computers, 25 percent of total investment; spectrometers, 22 percent; and bioanalytical instruments, 26 percent. These three categories encompass nearly three-quarters of the entire national inventory; all other types of equipment combined account for the remaining one-fourth (Figure 9).

Figure 9. Distribution of aggregate purchase price of academic research equipment, by type of equipment, 1988-89



Source: National Science Foundation, SRS

[10]This report gives a general overview of equipment type distributions and trends. For more detailed information about type-related equipment costs, uses, maintenance, etc., see *Characteristics of Academic Research Instruments, 1990* (NSF, 1991).

Overall Trends

At the level of these four broad categories, the composition of the 1988-89 national inventory is essentially the same as it was 3 years earlier: aggregate investments in all four categories increased about 50 percent over this period, resulting in no change in the allocation of investment among categories (Table 13). However, within each of the four broad categories, large shifts and changes are evident.

Computers and Data Handling Equipment

- Imaging equipment (graphics, computer-assisted design, and image analysis equipment) increased dramatically in prominence: the number of such systems, and the aggregate investment they represent, was about two and one-half times larger in 1988-89 than in 1985-86.

- Decentralized computer systems in the $200,000 to $999,999 range (i.e., systems administered at the school, department, or research center level, rather than through university-level computer centers) also showed substantial growth, with the overall number of and investment in such systems doubling in the 3 years since the last survey.

- Computer systems and components in the $10,000 to $199,999 range showed the lowest rates of expansion: as unit prices dropped from $42,000 to $35,000, aggregate investment in this category increased only about 30 percent (before adjustment for inflation). This finding does not imply any slackening of interest in personal computers or other computing systems at the low end of the cost range, however. The growing popularity and declining unit costs of such systems has meant that many of the systems being purchased now fall below the survey's $10,000 threshold.

Spectrometers and Light Measurement Equipment

- There are many different kinds of spectrometers. However, four relatively high-cost kinds account for about two-thirds of the current aggregate investment in this category (though only about one-third of the systems): NMR, mass, x-ray, and electron spectrometers.

- The number of NMR (nuclear magnetic resonance) spectrometers did not increase from 1985-86 to 1988-89; it may even have declined slightly. However, the average unit price of NMRs in the 1988-89 inventory was much higher than that found 3 years earlier ($152,000 versus $93,000 per system), resulting in a substantial increase in aggregate investment (from $100 million to $160 million).

- Electron/auger/ion scattering spectrometers also showed a substantial increase in aggregate investment (from $50 million to $100 million); this occurred as the number of such systems more than doubled, while (and perhaps because) the average cost declined, from $123,000 per system in 1985-86 to $100,000 in 1988-89.

Bioanalytical Instruments

- Average purchase prices for most kinds of bioanalytical instruments increased from 1985-86 to 1988-89. The largest increase was for protein (DNA) synthesizers/sequencers, whose mean price grew from $48,000 to $70,000. The number of these instruments also grew substantially, and the aggregate investment more than trebled, from $30 million to $100 million.

- The mean price paid for electron microscopes also increased considerably, from $105,000 to $120,000 per system. Thus, although the total number of electron microscopes in the national inventory did not change, aggregate investment rose from $130 million to $150 million.

- The number and average prices of cell sorters/cytometers both increased substantially, resulting in a doubling of the aggregate investment (from $10 million to $20 million).

- Centrifuges, the most numerous of the bioanalytical instruments, had a 40 percent increase in number and a 20 percent increase in unit price, resulting in about an 80 percent increase in aggregate investment (from $110 million to $200 million).

Table 13. Trends in aggregate amounts and average prices of academic research equipment, by type, 1985-86 to 1988-89*

Type of equipment	Number of systems			Aggregate purchase price		Mean price per system	
	1985-86	1988-89	Percent change	1985-86	1988-89	1985-86	1988-89
				(Dollars in millions)		(Dollars in thousands)	
Total	53,390	78,950	50%	$2,040	$3,180	$38	$40
Computers and data handling equipment	10,530	17,420	65	520	780	49	45
Graphics/CAD/image analysis	960	2,540	160	40	100	38	40
Other systems ≥ $200,000	250	490	100	90	180	378	354
Other systems/components	9,320	14,390	50	390	510	42	35
Spectrometers and light measurement equipment	8,910	12,510	40	450	700	50	56
NMR/magnets	1,120	1,060	10	100	160	93	152
Mass/GC-MS	640	920	40	70	120	115	133
X-ray (diffractometers, etc.)	840	1,220	50	50	90	64	75
Electron/auger/ionscattering	400	960	140	50	100	123	100
Other spectroscopy equipment	5,910	8,350	40	170	230	29	28
Bioanalytical instruments	18,450	25,450	40	520	820	28	32
Centrifuges	4,780	6,770	40	110	200	24	29
Electron microscopes	1,250	1,220	0	130	150	105	120
Other/unspecified microscopy	2,950	4,230	40	70	110	22	25
Chromatographs (except GC-MS)	3,700	5,290	40	70	120	20	22
Protein synthesizers/sequencers	680	1,440	110	30	100	48	70
Scintillation/radiation counters	4,120	4,290	0	80	80	19	20
Growth/environmental chambers	800	1,880	130	20	50	26	28
Cell sorters, cytometers	180	330	80	10	20	61	72
Other	15,500	23,580	50	550	870	36	37
Lasers, motion/optical analyzers	2,200	4,270	90	100	200	44	47
Electronics (cameras, recorders, etc.)	3,210	4,910	50	90	130	27	26
Temperature and pressure control/measurement equipment	2,140	3,840	80	70	90	31	24
Major prototypes systems ≥ $100,000**	250	590	130	70	150	267	248
Other***	7,700	9,970	30	230	300	30	30

*Estimates refer to research equipment systems costing $10,000 to $999,999.

**Includes all systems costing $100,000 to $999,999 not elsewhere classified.

***Includes all systems costing $10,000 to $99,999 not elsewhere classified.

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

SOURCE: National Science Foundation, SRS.

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- The number of growth/environmental chambers more than doubled, as did the aggregate investment in these systems (from $20 million to $50 million). Unit prices did not change.

- Scintillation/radiation counters, which were one of the most numerous kinds of bioanalytical instruments in 1985-86, did not increase in number or unit price or, consequently, in aggregate investment.

Other Instruments

- Laser systems and motion/optical analyzers almost doubled in number from 1985-86 to 1988-89, and the average price of these systems increased from $44,000 to $47,000, resulting in a doubling of the aggregate investment (from $100 million to $200 million).

- Miscellaneous, often custom-built, big ticket systems costing $100,000 to $999,999 more than doubled in number (from about 250 to about 590), as did the aggregate investment these systems represent (from $70 million to $150 million).

- There were a large number of miscellaneous instruments costing $10,000 to $99,999 that could not be classified in any of the above categories (almost 10,000 in 1988-89), but the number of and aggregate investment in such systems increased relatively little (about 30 percent), and the average unit price for such items did not change at all.

Trends by Field

Different fields show widely differing distributions and trends in the kinds of research equipment they have accumulated and in their top-priority needs for the future (Table 14):

- Computer science consists almost entirely of computing equipment, although small amounts of other kinds of equipment are also used, and needed, in that field (such as etching and MBE equipment used in designing circuit boards).

- Computing equipment also constitutes a substantial share (about one-third) of the existing inventory investment in engineering, the environmental sciences, and physics/astronomy. Chemistry and the agricultural and biological sciences have smaller investments in computing equipment (about 10 percent each). In all of the fields with relatively high investments in computing equipment, such equipment constitutes a lower share of departments' future needs than of their current inventories.

- Spectrometers represent a very large fraction (61 percent) of recent (1985) and current (1988) investments in chemistry, and an even larger (79 percent) share of top priority future needs in that field. Spectrometers are also becoming increasing prominent in most other fields, as well. This is especially true for the environmental sciences, where spectrometers represent a 50 percent share of future needs (up from 28 percent of current investment).

- Not surprisingly, bioanalytical instruments are especially prominent in the biological sciences, where they constitute 65 percent of current inventory investment; instruments in this category are also highly prominent in the agricultural sciences (52 percent of aggregate investment).

- Other equipment, such as lasers, electronics, and custom-built equipment of many kinds, are especially -- and increasingly -- prominent in engineering and physics/astronomy, where they represent about half of current inventory investment.

Table 14. Types of existing and needed* research equipment in selected science/engineering fields, 1985-90

Field and period	Total	Type of equipment			
		Computers	Spectrometers	Bioanalytical instruments	Other
	(Dollars in millions)	(Percent)			
Total					
Existing 1985-86	$2,040	25	22	26	27
Existing 1988-89	$3,180	25	22	26	27
Needed 1989-90	$1,520	21	27	21	32
Engineering					
Existing 1985	$[illegible]0	33	9	10	48
Existing 1988	$840	33	7	10	50
Needed 1989	$530	20	14	15	52
Agricultural sciences					
Existing 1986	$50	9	19	51	20
Existing 1989	$90	9	21	52	18
Needed 1990	$60	6	33	44	20
Biological sciences					
Existing 1986	$650	11	16	62	11
Existing 1989	$930	10	17	65	8
Needed 1990	[illegible]360	11	29	51	9
Chemistry					
Existing 1985	$340	10	61	7	22
Existing 1988	$550	10	61	8	21
Needed 1989	$130	16	79	2	3
Computer science					
Existing 1985	$110	97	0	0	3
Existing 1988	$160	98	0	0	2
Needed 1989	$100	92	0	0	8
Environmental sciences					
Existing 1986	$170	33	25	10	31
Existing 1989	$250	34	28	10	29
Needed 1990	$180	14	50	10	26
Physics/astronomy					
Existing 1985	$250	37	15	3	46
Existing 1988	$360	31	17	4	48
Needed 1989	$160	18	15	5	62

*From lists of three items per department/center of top-priority research instruments in $10,000-$1 million range. Needs lists include some items over $1 million and some that call for multiple copies (e.g., 10 workstations--$250,000).

NOTE: Percentages may not sum to 100 due to rounding.

SOURCE: National Science Foundation, SRS.

APPENDIX A

LIST OF SAMPLED INSTITUTIONS

Sampled Institutions

Nonmedical Colleges and Universities

Brown University
California Institute of Technology
Colorado State University
Cornell University
Duke University
Georgia Institute of Technology
Harvard University
Johns Hopkins University
Louisiana State University
Massachusetts Institute of Technology
Michigan State University
Mississippi State University
New Mexico Institute of Mining and Technology
North Carolina State University
Northeastern University
Northwestern University
Ohio State University
Oklahoma State University
Oregon State University
Pennsylvania State University
Princeton University
Purdue University
Rockefeller University
Stanford University
Stevens Institute of Technology
Temple University
Texas AandM University
Texas Tech University
University of Arizona
University of California at Berkeley
University of California at Davis
University of California at Los Angeles
University of California at San Diego
University of Central Florida
University of Colorado (Boulder and Denver)
University of Connecticut
University of Dayton
University of Denver
University of Illinois at Urbana/Champaign
University of Iowa
University of Kansas
University of Maryland at College Park
University of Michigan
University of Minnesota
University of Nebraska at Lincoln
University of North Dakota
University of Oklahoma
University of Pennsylvania
University of South Alabama
University of Texas at Austin
University of Washington
University of Wisconsin at Madison
Virginia Polytechnic Institute
Washington State University
Yale University

Medical Schools

Albert Einstein College of Medicine
Boston University Medical Campus
Duke University Medical Center
Johns Hopkins University School of Medicine
Mayo Medical School
Medical College of Ohio at Toledo
Northwestern University Medical School
Ohio State University College of Medicine
Temple University School of Medicine
University of California at Los Angeles School of Medicine
University of California at San Diego School of Medicine
University of California at San Francisco School of Medicine
University of Chicago Pritzker School of Medicine
University of Cincinnati College of Medicine
University of Colorado School of Medicine
University of Kansas Medical Center
University of Minnesota School of Medicine
University of Nebraska Medical Center
University of North Carolina School of Medicine
University of Pennsylvania School of Medicine
University of Texas Health Sciences Center at San Antonio
University of Texas Southwestern Medical Center
University of Washington School of Medicine
Yale University School of Medicine

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