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Instrumentation Needs of Research Universities

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Instruments are the tools with which researchers expand scientific understanding of the properties of nature. Their importance to the progress of science is indicated by the number of Nobel Prizes awarded for the development of instruments or methods of measurement. Within the past three decades, for example, Nobel Prizes in physics have been awarded for the discovery of nuclear magnetic resonance (NMR), the phase-contrast microscope, the transistor, the Cerenkov counter, the bubble chamber, the maser and laser, and holographic imagery.

Traditionally, research universities have played an integral role in the conception, development, and innovative use of instruments. For example, in 1928 Ernst Ruska, a beginning graduate student, began work on the first electron microscope. A half-century of development, based to a large extent on university research, has established the electron microscope as a powerful tool for the investigation of structure down to the atomic level. The development of instruments such as the flow cytometer has provided methods for conducting precise analyses of the chemical constituents of individual cells. As was true of the electron microscope, the flow cytometer was developed through a convergence of technologies.

Due to the rapid pace of instrument development, many instruments purchased only a few years ago are now obsolete. The 1960 Nobel Prize in physics was awarded for the development of the bubble chamber; today this technique has largely been replaced by electronic detectors such as drift chambers and wire chambers. F. Block and E. M. Purcell developed NMR in 1945 and 1946; enhancements of the technique (Fourier transform, signal-averaging methods, superconducting magnets) have produced an approximately 10,000-fold increase in speed and a 100-fold increase in sensitivity over the best equipment available only 10 years ago.

However, the cost of many new instruments threatens to make them inaccessible to many university researchers. The cost of multinuclear, high-field NMR spectrometers is approaching $500,000; flow cytometers cost up to $175,000. But without such instruments, the capacity of researchers to work at the frontiers of knowledge would be greatly impaired, and opportunities to develop superior instruments and expand their uses would be lost.

To assess the present capacity of universities to acquire necessary instruments, the authors, under the sponsorship of the Association of American Universities, conducted a study for the National Science Foundation (NSF) on the scientific instrumentation needs of research universities. The study examined the current status of scientific instruments in major research universities and sought to identify factors that facilitate or impede their acquisition, use, and development.

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Study Design

The project team visited 16 universities, six national and government laboratories, and nine commercial laboratories. Of the universities visited, eight are public and eight are private. Five public and five private universities were chosen from the 20 universities having the largest total federal R & D obligations in fiscal year 1977. Major research universities were emphasized because it was thought that this would identify the most critical national problems. To broaden the sample by rank and geographic location, six additional institutions were selected from universities with lesser R & D obligations in that year. National, government, and commercial laboratories were included to provide a context for assessing the university laboratories.

Working in close conjunction with a seven-member advisory committee of university and industry representatives, the project staff examined research instrumentation in physics, chemistry, biological sciences, earth sciences, and electrical engineering. In all, over 700 individuals were interviewed, including some 300 university researchers, department heads, and research administrators and approximately 60 researchers and research managers in national, government, and commercial laboratories. Numerical data on instrument acquisition and age were gathered from 14 universities and four commercial laboratories. Anecdotal data presented here were selected to be representative of the problems at major research universities. Where conditions were variable, the range of situations has been presented.

Summary. This article assesses the status of scientific instruments in major research universities and identifies factors that facilitate or impede their development, acquisition, use, and maintenance. Sixteen universities, six national and government laboratories, and nine commercial laboratories were visited; over 700 individuals were interviewed. Data on instrument acquisition and age were collected. Instrumentation was examined in physics, chemistry, biological sciences, earth sciences, and electrical engineering. The study found that the quality of university instrumentation has seriously deteriorated, due principally to a relative decrease in instrumentation funding, inflexibility within the project grant system, and insufficient support for maintenance.

Major Instrumentation Problems

Instrumentation needs vary widely within and among the universities and departments we visited. Although this diversity makes generalizations difficult, six major problem areas were identified:

1) *Acquisition and replacement.* University researchers are having great difficulty replacing worn-out or obsolete instruments and acquiring newly developed ones. Data from a major industrial research laboratory show that the total capital expenditures per scientist doubled from 1975 to 1979. In a recent study of the five important physicochemical subdisciplines, it was shown that the cost of scientific instruments priced above $5000 rose at an annual rate of 20 percent from 1970 through 1978, far exceeding the average inflation rate (*1*).

Table 1. Sources of instrumentation funding at universities visited (fiscal year 1979). The data are averaged over 68 departments and subdepartments at seven public and seven private universities.

Source of funds	Public (%)	Private (%)
Federal research grants and contracts	46	59
Federal equipment grants and contracts	14	19
Institutional sources	28	11
Capital construction funds	9	5
Other	3	6

Table 1 shows that most university instrumentation has been purchased with funds from federal research grants and contracts. However, in some fields it has not been possible to adjust the size of grants to keep pace with steadily rising costs.

To sustain the scope of their work, researchers must spend large amounts of time competing for grants from many agencies, both federal and nonfederal. Active scientists often require three or four current grants to maintain their research programs. Many investigators report that, while in the past they were able to meet most of their instrumentation needs through research grants, the increase in all research costs, combined with the relative decrease in the size of research grants, has left them unable to purchase all but the least expensive equipment through their grants.

2) *Start-up funds.* New faculty members require start-up funds to provide the instrumentation needed to initiate a competitive research program. These funds are now difficult for many universities and departments to provide; while the costs to equip research laboratories are rising, institutional sources of start-up funds are shrinking.

Table 2 provides an example of increased start-up costs in chemistry. The table lists the actual expenditures of a midwestern public university for equipping two new faculty members, one in 1970, the other in 1979. Also listed are the major shared instruments to which they required access. Each researcher was working in the same general field and had the same level of experience (Ph.D. plus a 2-year postdoctoral fellowship). In addition, each had the same basic assignments (teaching and research) at the institution. Both sets of instruments were used to investigate the same general phenomena, but the 1979 instrumentation allows analyses to be made with much smaller samples, saving time and money; furthermore, the results are considerably more accurate and specific. Indeed, the specificity and sensitivity required to make contributions to this field would be impossible without the modern devices listed.

Inflationary price increases are simply the rising baseline upon which are superimposed the frequently much larger cost increases resulting from advances in existing instruments and the advent of new ones. The price increases shown in Table 2 are equivalent to an annual increase of 22 percent for laboratory instruments and 23 percent for departmental instruments. In addition, the 1979 instrumentation requires more support equipment for its proper operation and maintenance, adding expenses not reflected in the table. Clearly, instrument capabilities have increased dramatically, but so too have costs.

The capacity to meet these increasing start-up costs varies greatly. The chemistry department at one midwestern public university can provide up to $70,000 for new faculty members and considerably more to recruit senior researchers. However, administrators at a southern private university can provide only $10,000 to $20,000 a year in start-up funds for nonmedical researchers—although on rare occasions they have been able to generate as much as $100,000 by pooling endowment resources over 2 or 3 years. The highly ranked western universities that we visited vary widely in their ability to provide start-up funds. Some report no difficulties; others have very low ceilings. The chairman of the biology department at a western public university reports that when he joined the department 15 years ago as a new faculty member, he received $30,000 in start-up funds; today the department can provide only $10,000, even though costs to equip a laboratory have increased substantially.

3) *Operation and maintenance costs.* Meeting the cost required to operate and maintain instruments is a ubiquitous problem for university researchers. The operation and maintenance burden includes expenditures for service contracts for commercial instruments, replacement parts, staff salaries and equipment for support shops, and, of course, operating the instruments. A researcher at a midwestern public university recently purchased a $30,000 cryogenic magnetometer; to operate the instrument requires $8,000 annually, principally for liquid helium. As another example, plasma tubes for an argon-ion laser have to be periodically replaced at an average annual cost of $10,000.

According to the chairman of the chemistry department at a midwestern public university, operation and maintenance costs could be supported by other budgets in the past, but now the costs exceed the capacity of institutional funds to meet them. When departments cannot adequately meet operation and maintenance costs, instruments are improperly maintained, shortening their useful life; support personnel are cut back and support projects pile up; faculty and students function as technicians, with a consequent loss of time for research and training. Obsolete instruments may be more difficult to operate and more likely to break down; manufacturers may refuse to renew service contracts; spare parts may no longer be available. These consequences can cripple a research program.

4) *Facilities construction and renovation.* Without adequate facilities, research programs cannot operate at full capacity. In the 1960's, substantial federal resources were available for the construction and renovation of research facilities. However, such support has diminished in recent years, placing an increasing strain on institutional funds.

Frequently there is a long delay between the decision to construct or renovate facilities and the acquisition of the necessary funds. With today's inflation, this delay can substantially reduce what the funds can accomplish. At a midwestern public university, inflation has effectively eliminated $250,000 from a planned $2 million wing to be added to a bacteriology department building; at a western public university, the time it is taking to raise $4 million for a biology building will likely cost at least one of its four floors. At one eastern private university, a new biology facility vital to the strengthening of the department has had to be abandoned.

Aging facilities impede research efforts. Recently, a malfunctioning distillation system in the zoology department building at a midwestern public university paralyzed research in the building for over a week. At a private university in the East, a promising program in contraception research was abandoned because the university could not meet new federal requirements for housing the dogs used in the research.

Animal facilities, greenhouses, and herbaria are particularly difficult to maintain. These facilities, tied as they usually are to building construction, are becoming old, but replacement and renovation funds are difficult to obtain through federal grants and are becoming extremely difficult to obtain from local sources.

5) *Support equipment.* Support equipment is instrumentation not directly involved in the measurements performed in experimental research but necessary to test, calibrate, or provide an appropriate environment for the core instruments. It includes oscilloscopes, vacuum leak detectors, and power supplies.

Difficulties in funding support equipment often arise not because of the absolute level of support but because the funds are targeted for other categories. A number of researchers report that specialized research instruments are more likely to be funded than routine, but important, support equipment.

6) *Inflexibility of funding.* Research is an ongoing process that rarely has distinct boundaries or a specifiable future course. Yet many investigators report that research funding is becoming increasingly inflexible. There is increased pressure for fast results. More paperwork is required. When gaps in funding occur there are no reserve funds to sustain research programs; valuable support

Table 2. Increased start-up costs for research: example from synthetic chemistry.

1970		1979	
Instrument	Cost ($)	Instrument	Cost ($)
Laboratory instruments			
Two Rinco evaporators	300	Rotovac evaporators	1,700
Two vacuum pumps	400	Preparative liquid chromatograph with fraction collector	7,200
Spinning band distillation apparatus	825		
Three solvent stills	600	Analytical liquid chromatograph with recorder and data system shared with capillary column	13,250
Melting point apparatus	150		
Gas chromatograph and recorder	1,450	Gas chromatograph	11,300
Hot plates, stirrers, heating mantles	275	Solvent stills with fire safety hoods	4,500
Glassware	500	Hot plates, stirrers, and heating mantles	600
Infracord infrared spectrometer	3,500	Microware with standard taper joints	3,000
		Glassware	800
		Thin-layer chromatographic plates and tanks	1,500
Total	8,000		43,850
Departmental instruments to which access is needed			
A-60 NMR spectrometer	40,000	90-mHz R-32 NMR spectrometer	52,000
Cary 14 ultraviolet/visible spectrometer	14,000	200-mHz wide-bore NMR spectrometer	225,000
Hitachi RMU-6 mass spectrometer	60,000	CFT-20 carbon-13 NMR spectrometer	80,000
Precision refractometer	2,500	Finnigan 4000 mass spectrometer and data system	160,000
		Cary 17 ultraviolet/visible/near-infrared spectrometer	32,000
		Digilab FT-infrared spectrometer	82,000
		High resolution mass spectrometer CEC-21-110	110,000
Total	116,500		741,000

personnel must often be laid off and may be irretrievably lost when such gaps occur.

A geologist at an eastern private university feels that peer review boards, operating under current constraints, fund only research deemed likely to produce specifiable short-term results. This, he believes, discourages investigators from pursuing long-term or high-risk research. A colleague, corroborating this view, states that he is able to develop essential instruments only by resorting to subterfuge.

Because of the increase in instrument costs, many investigators attempt to pool funds from their separate grants to purchase mutually needed instruments. However, rigid funding procedures often militate against such attempts at effective sharing.

Inflexibility in federal programs requiring matching funds for costly instrumentation also creates problems for universities. Success in meeting matching requirements varies widely. For example, certain chemistry departments have their own endowments and can usually meet matching requirements. On the other hand, some state universities receive little or no state funding for research equipment or related costs; for such institutions, matching requirements are a major financial problem.

Large matching requirements can generate long delays in acquiring needed instrumentation, even among institutions with substantial local funds. An eastern private university was required to provide \$150,000 of the total cost of \$300,000 for a high-field NMR spectrometer. Difficulty in raising the funds impeded the department's research efforts for more than a year. In effect, such delays deprive the nation of the research for which federal funds already have been obligated.

Variations in Problems

Across Disciplines

Each discipline has its own unique instrumentation problems. In physics, maintaining adequate support shops is difficult. The cost of service contracts is a major financial burden to many biology departments. Instrumentation in high energy physics, surface chemistry, and microcircuitry has become extremely costly. Some schools have begun closing off certain areas of research because they have become prohibitively expensive.

Because much of their equipment must be specially designed and fabricated, physicists are heavily dependent on support facilities and staff. We received several reports of graduate students being used as technicians far beyond levels justified educationally to compensate for insufficient technical support.

Chemistry has evolved from a benchtop science into a predominantly equipment-intensive discipline. In natural products chemistry, even one of the best-funded institutions visited has outmoded instruments. An industrial research administrator notes that inadequate support for the electrical engineering field of microcircuitry is fast becoming a "national disgrace" because of the inability of most departments to acquire the instruments required for advanced training.

In the earth sciences, equipment needs vary according to the subdiscipline. While laboratory experiments such as those simulating the pressure and temperature of the earth's crust are important, field data are essential. Because the earth itself is the laboratory, acquiring data is difficult and costly. Ships, satellites, and computers are essential to some programs. Large-scale, cooperative efforts such as those mobilized in seismic studies of volcanoes and earthquakes are often required. Geochemistry has been revolutionized through the use of the electron microprobe, the mass spectrometer, and the scanning electron microscope. With the advent of the ion microprobe, geochemistry research has become dependent on the extremely expensive analytical tools of modern chemistry.

Biology departments work primarily with commercial equipment and therefore rely heavily on service contracts. These costs have increased substantially during the past few years and have become a major financial burden for many departments. In an eastern molecular biology laboratory, the average cost of service contracts for centrifuges increased approximately 100 percent between 1975 and 1979 (from \$379 to \$752 annually per instrument). Despite the growing importance of large-scale instruments to biology, state-of-the-art electron microscope facilities in the major research universities have deteriorated.

Severity of the Problem

Most of the university laboratories visited fare poorly in comparison to the nonuniversity laboratories. For example, the government laboratories have more (if not always better) instruments and more extensive support facilities; and they rarely experience serious backlogs of research support projects. Several laboratories have extensive programs of instrument development. While these vary in quality, instrument development in university laboratories, in contrast, is being squeezed out of many research programs.

There is a surprising degree of variation in the quantity and quality of instruments in the commercial laboratories visited, but the best surpass almost all university laboratories visited. Figure 1 compares the age distribution of the current inventories of university and industry instrumentation purchased from 1960 to 1978. The inventories do not include instruments that are unusable due to age or disrepair. The curve for universities represents data from ten institutions, pooled across the five disciplines for which data were gathered (*2*). The curve for industry represents data from the research laboratories of two major profit-making companies.

The figure reveals a striking disparity in the age of university and industry instrumentation; the median age of the university instrumentation is twice that of the instrumentation in the two industrial laboratories. The philosophy of both industrial organizations is to fund instrumentation at a level such that ideas, rather than instruments, are the rate-limiting factors in research. As profit-making organizations, these companies are nonetheless concerned about the cost-effectiveness of their expenditures, and both have policies encouraging instrument sharing.

The capacity of industrial laboratories to mobilize resources rapidly to exploit suddenly arising opportunities provides one of the greatest disparities between these and university laboratories. Even well-instrumented university laboratories were typically assembled through acquisitions over a number of years. The director of an industrial research laboratory states that it is "pathetic" to see distinguished university researchers struggling to acquire needed instruments by bits and pieces. In contrast, on high-priority projects, industrial researchers can acquire all the instruments they need when they need them.

Scientists in commercial laboratories are not burdened by the administrative paperwork required for the acquisition of research funds and required by related reporting obligations. Indeed, as one university researcher sardonically states, "The ivory towers are now in industry."

However, in some fields, university researchers frequently observe, even the best industrial laboratories in this country do not compare with the foreign laboratories that they have visited or worked in. When asked to identify the best-equipped laboratories in their fields, many scientists mention foreign facilities, particularly Japanese and Western European laboratories.

While investment in R & D by both the federal government and industry has declined in this country, it has been increasing in foreign countries, most notably Japan, West Germany, and the Soviet Union. Research in American universities may remain competitive with research carried out in industrial and foreign laboratories by compensating for the lack of instruments and laboratory facilities with people. The capacity to cope by substituting intellectual ingenuity for instruments, however, will likely be nullified if present trends continue.

Assessing the Situation

The deteriorating quality of university instrumentation is threatening the capacity of even the best institutions to conduct research and provide first-rate training. This deficiency retards the pace of research because the energies of research scientists and graduate students must be redirected from innovative investigation to subsistence activities. Both new and old lines of inquiry are being closed off because of difficulties in obtaining essential but costly instruments.

University scientists often expand the capacities of existing instruments through modifications made in the course of their research. A recent study showed that of 44 improvements that were incorporated into a commercial instrument, 32 were contributed by university scientists (*3*). But lack of access to state-of-the-art instruments and sufficient support facilities may diminish the role that universities play in making such contributions. Also, since over half of the nation's basic research is conducted in universities, the deterioration of university instrumentation may have serious consequences for U.S. science in terms of international competition.

We identified three causes for the severity of instrumentation problems in universities:

1) *Decreased federal support*. Federal support for basic academic science has not kept pace with the rapidly rising costs of conducting research. Strained local budgets in many universities cannot compensate for declining federal funding. Funds for instrumentation have been severely curtailed. For example, the proportion of funds allocated by the National Institutes of Health (NIH) for laboratory equipment declined from 11.7 percent in 1966 to 5.7 percent in 1974 (*4*). Scientists report that they often do not request needed instruments for fear of jeopardizing the basic proposal. To accommodate restricted budgets, the principal investigators, peer review committees, and program officers preserve research manpower and trim instrumentation and support equipment from proposals. This reflects the fundamental importance of scientific and technical staffs to the strength of research programs and the need to maintain the training mission of universities. However, the continued choice of personnel over instruments will lead to further deterioration in the quality of instruments available to conduct research. The academic research system is consuming its capital, and the grace period during which the system can operate effectively on earlier investments is ending.

2) *Inflexibility within the project system*. Current regulations make it very difficult for researchers to pool expenses for acquiring and maintaining instruments to be shared among their projects, especially when the support is provided by different agencies. These regulatory barriers impede the efficient utilization of instrumentation funds that do exist and ignore the research benefits gained when instruments are shared and costs are appropriately pooled (*5*).

3) *Insufficient support for maintenance*. Inadequate provision for maintenance often leaves instruments dysfunctional for extended periods and decreases their effective life. Even when researchers and their students are able to compensate for the lack of maintenance support by performing such necessary tasks themselves, they must do so by diverting valuable time from research and training programs.

Current Government Programs

Federal funding of university instrumentation comes from a number of sources, principal among them the following:

1) *The project grant system*. This system has been very successful in channeling federal funds into high-quality research, but intense competition for the limited funds available has adversely affected instrument acquisition.

2) *Special instrumentation funding programs*. These programs, such as those sponsored by NIH and NSF, have been helpful in supplementing the project system and encouraging the sharing of expensive instruments. However, a number of these programs do not support installation, housing, or operation and maintenance costs and require that the university provide matching funds that are often difficult to acquire from local sources.

3) *Formula grants*. These institutional awards are established on a formula that is related to some segment of the annual federal R & D project funding of the institution involved. The biomedical research support grant (BRSG) of NIH is generally considered to be the most important and successful of the existing formula grants. Funds provided by BRSG's, although limited, have proved effective in supplementing local sources to meet start-up costs and other instrumentation needs. The NSF administered a formula grant program from 1961 to 1974; over half the funds provided were used to acquire instruments (*6*).

4) *Block-funded research centers*. These centers, such as the materials research laboratories funded by NSF, provide stable sources of instruments. Directors and investigators utilizing the centers point out their flexibility, efficiency, and ability to successfully foster instrument sharing. However, their scope is narrow relative to the full range

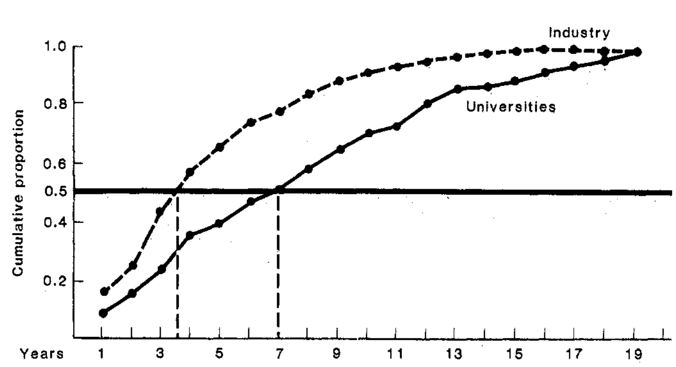

Fig. 1. Mean age of instruments in universities compared with that of instruments in industry (proportion of instrumentation inventory purchased less than *n* years ago). Values for universities are averages of the data for 54 departments and subdepartments of ten institutions; values for industry are averages of the data for two major industrial research laboratories.

of university research, and few institutions have them.

5) *Regional programs*. A number of regional instrumentation programs have been developed. For example, in 1978 NSF devised a program to provide regional access to expensive state-of-the-art analytical instruments. At some level of cost, it is clear that regional or national facilities are necessary—that the instruments required to support the research are simply too expensive to remain under the purview of the individual researcher, a single department, or even an institution. The high energy physics community has faced this problem for years.

However, there are several difficulties in working through regional centers. These include the time and expense of travel, inadequacy of the centers for training, and delays in obtaining experimental results. The facilities are also perceived by many to foster conservative science because the time and expense involved in their use creates a reluctance to undertake high-risk experiments. The centers are young, and some of their problems can be ameliorated; others, however, are inherent to regionalization.

In creating new programs, the choice of providing instruments on an individual, university-shared, or regional basis must be carefully evaluated in terms of the trade-off between such factors as instrument cost, expense of time and travel, and the flexibility and vitality of laboratory-based research.

Recommendations

Identification of the causes for deterioration in the quality of university research instrumentation suggests policies that could rectify the situation. Federal policy for the support of research instrumentation requires new funding mechanisms emphasizing flexibility as well as additional funding. We propose the following funding strategy:

1) *Strengthen instrumentation funding in the project system*. Program managers are generally well aware of instrumentation funding problems but are forced to make unsatisfactory compromises due to limited resources. Increased support through individual research grants and contracts is needed. This would alleviate many of the problems documented here. To accomplish this, the size of individual awards must be increased and a larger percentage of funds allocated to the development, acquisition, and maintenance of instruments. Instrument sharing must be encouraged, and regulatory barriers to the pooling of resources must be eliminated.

However, the project system is not designed to meet the special problems of acquisition of expensive (usually shared) instruments, nor does it effectively address problems such as the funding of departmental support facilities and staff, start-up funds, and matching requirements. The system lacks the flexibility to allow researchers and their institutions to meet unexpected local needs and seize opportunities. While it is, and should remain, the primary mechanism for the support of instrumentation, the project system cannot meet the full range of instrumentation needs by itself even if additional funds are provided.

2) *Expand special programs for funding instrumentation*. Expansion of the special funding programs, with provisions to ease the financial burden on institutions forced to meet stringent matching requirements, is a second important means to increase the level of instrumentation funding. University contributions toward the housing, operation, and maintenance of instruments should be considered part of the matching requirement. This would provide not only a means of upgrading major instruments but also ensure their continued availability.

3) *Encourage increased industrial support for university instrumentation*. Industry is dependent on universitites to train its scientists and engineers. To conduct training at the frontiers of science, universities need state-of-the-art instrumentation. Industry can support university research and training programs by providing essential modern instrumentation or funds for its acquisition. The federal government should develop incentives to encourage such industrial support. While industrial support can play an important role in the acquisition by universities of state-of-the-art instrumentation, it should be noted that such support would be distributed unevenly across disciplines.

4) *Create in NSF an instrumentation renewal program with flexibility to meet diverse institutional needs*. In our judgment, a carefully designed new program, restricted to instrumentation and directly related needs but allowing local allocation decisions, would be the most effective means of providing the flexible funding required to meet the great diversity of needs that exist across departments and institutions. Instrumentation funds would be awarded to institutions in proportion to the total NSF research support they receive. In that way, these funds would follow the research funds awarded by NSF. The program would operate under the guidance of a university committee of faculty members and research administrators who are in the best position to evaluate the unique instrumentation needs of their institution.

This mechanism would provide a local source of flexible funds that could help provide start-up money, support instrument acquisitions for senior investigators seeking to branch into new areas, meet matching requirements, fund the facility renovation often required with the acquisition of new instruments, purchase support equipment, meet operation and maintenance costs, and fund departmental support facilities and staff.

The strongest impression arising from our university visits is the diversity of problems confronting different universities and different departments within the same institution. A source of supplemental, flexible funds would allow researchers and their institutions to respond quickly to unanticipated needs, to capitalize on unique local strengths and opportunities, and yet to remain fully accountable for federal research funds. These funds could be used to address all three causes of the decline in university instrumentation in a manner best suited to the local needs of each institution. No other funding mechanism, in our view, would have a more immediate and direct salutary effect.

References and Notes

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3. E. von Hipple, *Res. Policy* **5**, 212 (1975).
4. B. Smith and J. Karlesky, *The State of Academic Science* (Change Magazine, New Rochelle, N.Y., 1977), p. 168.
5. The NSF recognizes the inflexibility created by regulations, and, working in cooperation with the Association of American Universities, is conducting an experiment in which researchers are delegated the authority to allocate funds among related research projects, except where such allocations would involve a change in project scope or principal investigator. The experiment has been quite successful and is being expanded to more fields and institutions.
6. J. G. Danek, *Diss. Abstr. Int. A* **37-06**, 3533 (1976).

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