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$$w_{12t+1} = 1.289p^n[1-(1/z_o)] + 1.075 \quad (7)$$

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Academic Science and the Federal Government

Philip Handler

Responsibility for the welfare of American science with commensurate financial support of research and education in science is a recently established role of the federal government. The rapid growth of this endeavor has occasioned numerous searching inquiries by the executive and legislative branches of the government, by the academic community, and by the press. A growing literature reflects deepening concern with the relationship between science and society, and seeks to develop an appropriate base in philosophy and understanding to guide those responsible for government science policy. This article is intended to provide a more immediate focus for some aspects of this discussion.

Although the Constitutional Convention of 1787 explicitly rejected efforts to grant the federal government constitutional authority for the pursuit of scientific inquiry, over the course of the next sesquicentury that government found itself increasingly involved with science and technology. Nevertheless, before World War II, except for federal support of the state agricultural experiment stations and the highly selective actions of a few philanthropic foundations, research was largely financed from the meager operating funds of those institutions in which it was conducted, that is, universities, a few research institutes, and government laboratories. After the war, augmented support for basic research was provided from funds which, in the American tradition, had been collected or appropriated to further distinctly applied missions, such as a hoped-for cure of cancer or a new weapons system. Private support, particularly of biomedical research, increased greatly, but, by the mid-fifties, the federal government had been established as the major patron of science in our country.

The Office of Naval Research embarked upon an enlightened course of programs for support of research in almost all areas of science. The National Science Foundation was charged with assuring the vitality of American science. As its appropriations increased, the Foundation developed a panoply of individual programs in support of research, science education, and scientific information. Withal, NSF is today responsible for only 15 percent of federal support of research at academic institutions proper. The National Institutes of Health multiplied and, by means of a diversity of programs in support of biomedical research and research training, transformed the nation's medical schools while also strikingly upgrading many departments of biology and chemistry. New agencies, organized to manage exceptionally large enterprises—exploitation of the potential of nuclear energy and the exploration of space—also found it useful to engage the academy in their programs, while the other military services followed the earlier lead of ONR. Occasionally, proponents of a Department of Science appeared, but their proposals were rejected and, instead, there evolved a pluralistic pattern of support not only of specifically mission-oriented research, but of fundamental research at the frontiers as well.

By the historical accident that a pre-

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ponderance of the nation's most competent scientists were on university faculties at the time of World War II, and no tradition of government-supported research institutes had previously been established, universities, collectively, became the seat of the major thrust of fundamental research in the United States, a pattern strikingly different from that of many European nations, most notably the Soviet Union. This unplanned development engendered a uniquely successful system of graduate education within which education and the conduct of research are indistinguishable: young scientists are given meaningful research opportunity at what may be the most productive stage of their careers; and the endeavor occurs within coherent departments which are frequently of a magnitude sufficient to exceed the minimal critical intellectual mass essential for success. The enterprise nurtures not only the few highly talented young people who will become tomorrow's scientific leaders, but also the much larger numbers of scientists needed to staff our educational institutions, government and industrial laboratories and, in so doing, take full advantage of the accomplishments of those highly talented few. This may well be the prime basis for the "technology gap" between the United States and those European nations which contribute their share of effective, highly talented scientists, but fail adequately to capitalize on their contributions. The patent success of this educational endeavor seems all the more remarkable since it has been accomplished, largely, by funding mechanisms designed to support research qua research, rather than graduate education, and is administered by federal agencies which are charged with a diversity of "practical" missions. But the rapid growth of this research-education enterprise has seriously stressed the universities. And it is not surprising that a system designed to purchase research results, albeit with the understanding that their application may lie in the relatively distant future, is not entirely satisfactory as the primary financial pillar of graduate education.

Political Setting

Unfortunately, during this period of growth, the academic scientific community failed to communicate to the public the integral nature of graduate education and the research process. While the press, understandably, publicized the occasional peaks called "breakthroughs," there was no equivalent effort to make explicit the manner in which research findings combine to form the mosaic which is the corpus of science and which contributes continuingly to applied research and development. Hence, it is entirely understandable that public sentiment currently urges a rationalization of the nature and magnitude of the academic research endeavor and its place in American society. Public appreciation of remarkable technological achievements in fields such as space, weapons, communications, and computer development engendered confidence that federal research programs could also ameliorate some of the more pressing problems of American society. As the term "fundamental research" latterly assumed less generous nuances of meaning in the public ear, such alternate motifs as "education," "regional development," and "equitable distribution of federal funds" became increasingly attractive on the federal scene. And there is a growing opinion that there is a relationship between the economy of a given region and the quality and magnitude of the university science endeavor within that region.

From many quarters came demands for upgrading the quality of American education at all levels and in all regions, finally tumbling the traditional barriers to federal aid to education. Without national debate, there is increasing feeling that the nation should provide every student with access to the maximum level of education which he can successfully achieve. (As a subtle consequence, whereas previous projections concerning the growth of the academic research endeavor were made in terms of the numbers of competent scientists who could be envisioned at their benches at some future date, it has now become more expedient to base such projections on estimates of graduate student enrollment at that date.)

The current decline in the rate of growth of national expenditures for science is serious indeed. Most critically affected will be young scientists fresh from postdoctoral experience and eager to try their fledgling scientific wings, particularly those who have been attracted to emerging young institutions. Although indicators of this difficulty are already evident, it is not yet maximal since there is a substantial lag period between passage of congressional appropriation bills and their impact on the distribution of grants and contracts. In some degree, the currently diminished growth rate of federal funding of fundamental research has been compensated by provision of funds ostensibly in support of education and by the, as yet, lesser effort to encourage the upgrading of the scientific endeavor in the so-called middle universities as well as in institutions of higher education generally.

When, however, the Vietnamese episode terminates, it is possible that funds on a scale larger than any in history can be made available for the support of fundamental research, graduate education, and the institutions in which these are conducted. It is imperative that at that time, the nation be armed with long-range plans based on a debated and understood philosophy and defined goals.

Limited Partnership between Government and the University

Perhaps the most important lesson to be drawn from the immediate past is that our nation should continue to capitalize on the mutually beneficial relations of graduate education and research. The support of university-based research in the natural and social sciences simultaneously and indivisibly serves diverse purposes which are of equivalent value to society. The funds so utilized make possible the education of those who will be tomorrow's teachers, investigators, and administrators; they expand the frontiers of man's understanding of himself, his society, and of the universe, while providing scientific bases both for tomorrow's technology and, hopefully, for tomorrow's social forms; and the very endeavor itself establishes the tone and quality of life, not only for those immediately at the university or in the region about it, but for the nation at large.

These may appear to be self-evident truths, but this unitarian doctrine has not been universally accepted. Witness the pretext that graduate instruction and the research endeavor of the university are separable entities for bookkeeping purposes. This is expressed in the guidelines for "effort-reporting" associated with federal grants and contracts, an arrangement wherein each investigator-teacher is required, periodically, to report the fraction of his

"time or effort" devoted to the research supported by each specific research grant or contract. This intrinsically farcical contrivance arose from the limited nature of the partnership between government and the university. In the law, the mission-oriented agencies may have no commitment to the welfare of the university per se. Hence, it became logical to expect that, if the salary of the investigator-teacher is to be defrayed, in whole or in part, by an agency which supports his research but may bear no responsibility for his teaching function, then that agency must assure itself that the extent to which the investigator-teacher has contributed to each of his sponsored research projects is commensurate with salary payments from the related grants or contracts. Since neither the intensity nor the quality of this contribution is quantifiable, the units of contribution, willy-nilly, must be reckoned in *hours*.

On its side, the university entered into this arrangement because by this means the university can look to the federal government for a contribution to its operating budget. The brute fact is that universities, particularly the private universities, lack the funds to meet the costs of the multitude of functions expected of the multiversity in contemporary society. Today, increasing numbers of well-prepared undergraduates arrive on campus with expectations of personal encounter with faculty minds, expectations which surpass those held by graduate students only yesterday. This worthy challenge can be met only by a commensurate increase in the numbers and quality of the faculty and, hence, in the budget. The commitment of the university to graduate education, inherently the most expensive form of education since it is essentially tutorial, has grown as increasing fractions of undergraduate classes have accepted the proposition that graduate or professional education is almost imperative to life in an ever more complex society. But the university offers community services well below cost, frequently gratuitously, while undergraduate education is made available at perhaps one-third of true cost, and graduate and professional education for lesser fractions still. Indeed, since the university typically "recovers" 70 to 95 percent of the true costs of federally supported research, despite the overall magnitude of this effort, it may have become, *financially*, the least painful of the university's several increasingly expensive roles. And neither tuition nor private giving is likely to alleviate this situation.

On every university campus, while responsible educators insist that undergraduate and graduate education were never as good or as intensive as today, deficits rise and some institutions approach insolvency. If, as the more vocal undergraduates insist, educational programs are nevertheless, inadequate, the problem is not so much that universities are unresponsive or conservative—they are and should be deliberate in the face of pressures to change—but that they lack the resources with which to respond as they might wish.

Confronted with these urgencies, the universities have turned to federal funds, appropriated in support of research, for assistance in the payment of faculty salaries. When this logically gave rise to the practice of effort-reporting, the university professor, working full time, was caught in a trap not of his making and asked to submit a statement concerning the extent to which he has given of himself to but one aspect of his profession. Aware of the intrinsic impossibility of a meaningful reply, teacher-investigators in every university have protested.

But the problem is not how to keep books of account for professorial salaries. Rather the real questions are, "Are American private universities, presently responsible for about one-third of undergraduate education and a yet larger share of graduate education and research, worth salvaging? Is the private university sufficiently valuable to American society as to warrant direct subvention? Should the federal tax base be utilized for large-scale contribution to the general operating funds of both public and private universities? If so, by what mechanisms?" Effort-reporting is no less repugnant to the faculties of public universities, but it is the problems of private universities, in the main, which resulted in current practices. However these questions are answered, it is imperative that professorial salaries be removed from the project research grants system and that the requisite funds be conveyed to the universities in a manner which is supportive rather than destructive of the morale of those whose creativity, insight, and understanding form the keystone of the entire education and research enterprise.

Indirect Costs, Cost-Sharing, and Effort-Reporting

Three major changes in the management of research grants programs were initiated almost concurrently.

1) In response to repeated requests by university presidents and business administrators, Congress acquiesced to the principle of payment of full indirect costs in association with research grants funded by the National Institutes of Health and the National Science Foundation.

2) Simultaneously, Congress enunciated the principle of cost-sharing and established as equitable a distribution in which the university would bear at least 5 percent of the sum of direct and indirect costs. Since this principle had the effect of negating, in part, the consequences to the university of the former action, the universities were quick to recognize that the position could be recovered if they were to request, in applications for research grants, an increasing fraction of the associated professorial salaries. However, few took full advantage of this opportunity on the scale legally possible. The agencies were thus spared an embarrassment since Congress had not also provided equivalent additional funds; otherwise the net result would have been an absolute decrease in funds available for the conduct of research, per se. In any case, it soon evolved that the principal financial contribution that the universities could offer, in token of cost-sharing, was some fraction of the associated faculty salaries.

3) The practice of effort-reporting was initiated, in part for the reasons stated earlier, and in part out of the alleged necessity for formal demonstration of the extent to which the university participates in cost-sharing. In those instances in which the investigator actually is engaged full-time on the research project, this occasions relatively little pain. When the investigator-teacher's salary is defrayed entirely from university sources, the amount of "effort" required to satisfy the cost-sharing principle is almost invariably less than the actual case; whereas he may safely certify this contribution with complete honesty, he is irate when asked to account to the government for work for which he was paid by the university. Ironically, very few academic scientists have protested when asked, in applications for research

funds, to estimate in advance their expected effort contributions! When, however, the university requests the maximum fraction of the investigator's salary possible under the cost-sharing formula, to the auditor it can be a matter of considerable moment whether the investigator contributed 40 or 60 percent of his effort to the project in question, whereas the latter cannot reasonably be expected to know the difference.

In the minds of many, these three independent concepts and practices have blurred into one and this has led to vigorous attacks on the principle of cost-sharing. For example, the National Association of State Colleges and Universities and the National Association of State University and Land-Grant Colleges requested an end to the cost-sharing principle and proposed that the federal government should defray the full costs of academic research including the full pro rata fraction of the professor's salary attributable to his sponsored research. To be sure, serious inequities have arisen in the administration of the cost-sharing principle, but these have resulted largely from failure to reckon the transactions between an agency and an institution colligatively instead of individually; that is, the institution may not compensate for undercost-sharing in one grant by overcost-sharing in another.

Abandonment of the cost-sharing principle could plant the foot of the university on the highway to disaster. Current accounting and reporting mechanisms and the granting instruments themselves may well be inappropriate —but retention of the cost-sharing principle is essential to assure the independence of the university, particularly the private university. To do other is to accept the notion that the government purchases from the university research which the government wishes to have performed, whereas they are and should be joined by the mutuality of their interests and the transaction should occur in the spirit of a grant-in-aid. A true university must view the conduct of research as an integral aspect both of graduate education and of its responsibility to society. Full payment by the federal government of research costs including professorial salaries is a denial of that concept and could constitute the first major step along a trail by which it would become a federal university. This may appear to some to be a desirable or realistic goal; but the trail should not be broken until it is clear that the goal has been accepted. If, indeed, there is merit in the survival of the private or state university, albeit in loose partnership with the federal government, then American society must invent new means by which these institutions are to be sustained.

I urge that the university should be enabled to meet the faculty payroll and provide all those services currently reckoned as "indirect costs" from otherwise uncategorized funds, regardless of their source, even if this is large-scale direct subvention by the federal government. Then it would be free to engage, in equivalent proportion, in cost-sharing in its undergraduate, graduate, and professional education programs, its community services, as well as in its research endeavor. Were the direct subvention ample, the problems of cost-sharing and faculty effort-reporting would be automatically eliminated. To be sure, payment of full direct and indirect costs by federal agencies, on a grant-by-grant basis, in extension of current practices would lighten the financial burden on universities. But as long as individual project grants and contracts, particularly those from the mission-agencies, include payments for faculty salaries, time- or effort-reporting will necessarily continue, as will the continuing erosion of the allegiance of the faculty to the university and the all-too-frequent disavowal, by the university administration, of responsibility for its research endeavor. Elimination of these trying problems will require drastic revamping of research and university support mechanisms and concerted action by all federal agencies, probably including designation of one agency as "principal federal agent" for a program of university subvention either by a minimum program of grants for payment of faculty salaries or, hopefully, a generous formula based on student enrollments, and the magnitude of the institution's research enterprise which more adequately permits the university to function as our society demands.

Summer Salaries

Early in the history of the federal grants programs, sanction was given to payment of the investigator's salary, on a pro rata basis, for that portion of a calendar year which is not included in the academic year. Most frequently, this has meant a 2/9 increment above the academic year salary. The practice was adopted before academic salaries had risen in keeping with the general postwar inflation and was intended to permit the investigator-teacher to continue his research rather than necessarily utilize the summer as an opportunity to earn additional income in a nonacademic setting. This course was enormously successful and, indeed, also contributed significantly to the professionalization of academic research.

But once such a privilege has been extended to one investigator, it cannot be witheld from others. In time, such supplements became the norm and were so accepted and expected by academic administrators in preparation of their budgets and pay scales. Concomitantly, academic salaries increased significantly, thereby posing a serious problem to the agencies. A supplement which helps assure a minimum decent income is readily understood. But is there some ceiling which is equally logical? How should an agency react to a request for a 22-percent supplement to an academic salary which exceeds the 12-month salary of the agency head? Should the agencies consider some maximal annual total rate, or some maximum rate of summer payment? Patently, any such modification of the present arrangement is a step toward federal establishment of academic salaries. And again, a rational solution requires federal subvention of the university rather than of individual investigators through the project grant system.

Institutional Development

Pressure to upgrade the scientific activities of universities which are not currently in the very front rank arises from the generally enhanced expectation of Americans everywhere with respect to the quality of life and from the belief that the science endeavor at a university contributes significantly to the life and economy of a region. This was certainly the role of the agricultural schools of the land-grant universities in the flowering of the agricultural revolution; it should be true of all universities in the scientific revolution.

Economists are divided on the extent to which regional economic vigor re-

flects the scientific quality of its focal university; indeed some argue the converse, that it is the vigorous economy which supports the great university. But there are examples of successful stimulation of the life and economy of a region by deliberately capitalizing on its university base. The proximity of North Carolina, North Carolina State, and Duke universities, "middle universities" all, prompted the development called the Research Triangle. This attracted substantial industrial and federal laboratories; in turn, these attracted others and the community benefits by the second and third harmonics of this activity, ultimately including better shops, better bookstores, more theatre, and so on. All increased the local tax base, giving rise to better community services and better schools, while attracting yet more industry and industrial research, and the sum of these, in turn, strengthens the universities. Such a growth cycle is not the automatic consequence of the presence of the university: it must be fostered by vigorous community effort. But it can be done where the university is sufficiently strong. How many such developments the country can successfully undertake in the next 5 or 10 years remains to be determined.

The scale and pace of attempts to upgrade universities across the country require careful analysis and planning. The process must be incremental and the pace must be set by the availability of the necessary students, scientists, physicians, and engineers, avoiding actions which might diminish the quality of science at the already established institutions; indeed, the latter must continue to progress if they are not to retrogress. To be successful, this effort will require substantial federal funds and entail individual actions made on a scale substantially greater than that possible in the present programs of NSF and NIH. Careful planning at national, regional, and state levels must resolve the recurring problem of whether to assist relatively large numbers of institutions, in small increments, or to attempt truly major measures at a few, carefully selected institutions. In either case, success of the undertaking may be estimated by the subsequent success of the faculties of these institutions in competing in the national research grants system. Meanwhile, those engaged in such bootstrap operations must cultivate patience. To cite the report of a committee of university presidents, "While other activities of the state may be improved by rapid administrative reform, the university must build its greatness and efficiency over decades."

As junior colleges and universities increase in number and size, the traditional 4-year college finds itself in a difficult plight. Most serious is its increasing difficulty in attracting faculty of the desired caliber. No simple solution is obvious and it is unclear whether, in the future, the isolated 4-year college can remain a viable organism in our society. But the transformation of formerly admirable, relatively small, private liberal arts colleges into third-rate universities by inauguration of inadequate programs of graduate education is surely an error to be avoided, if only because launching a good university is more readily accomplished than is improvement of an inadequate university. Equally thorny is the increasingly frequent problem of the state college which, having attained a large enrollment, aspires to become a graduate university although its faculty is not commensurate with the demands of graduate education. State educational planning boards would be well advised to avoid this snare by early identification of those institutions to be designated as graduate universities.

In contrast, there are some federal contract research centers and in-house federal laboratories which can boast of research staffs at least equal in caliber to those of most universities and which are engaged in research much of which does not differ in character from the research which is normal in the programs of graduate universities. Several of these laboratories contribute significantly as training grounds for postdoctoral fellows; none are thoroughly exploited as resources for graduate education. As the existing network of universities becomes saturated and as the demand for graduate education becomes more pressing, it will become urgent that the resources of these laboratories, their facilities, and their scientists become more fully engaged in the educational enterprise.

Funding Patterns

It is imperative that we preserve the patent merits of the project grant system while developing mechanisms for the support of science and science education by the transfer of funds in larger amounts than are customary today. As a governing principle, funds for a given purpose should be made available to the largest unit concerning which a qualified group of external referees can make an appropriate quality judgment.

1) Unusually large facilities which serve the national scientific community, whether radio telescopes, accelerators, or sociological data banks, and so on, are most appropriately managed by consortia of universities, in-house federal laboratories, or single universities serving as federal agents.

2) Grants for general university subvention, blocks of faculty salaries, construction, libraries, large computer centers, institutional science development, shops, animal or other large special facilities should be conveyed to the university president or the appropriate dean.

3) Block grants to provide, *inter alia*, stipends for graduate students, general research services and the research expenses of junior members of the faculty should be made available to department chairmen or their equivalent. Instead of the widespread practice of supporting graduate research assistants with stipends derived from research grants made to their mentors or expanding current federal competitive fellowship programs by more than an order of magnitude, graduate students should be supported almost entirely from such departmental grants, an extension of the concept established in the present insufficiently funded training grants of NIH and NSF.

4) Funds appropriate to the unique requirements of the individual investigator should be awarded in his name, after assessment by the now traditional peer-judgment system. Most of the other grant mechanisms should rest on assessment of the collective ability of the applicant group in question (a department, school, or university) which, in turn, must generally be the aggregate of quality judgments concerning individuals. There have been frequent expressions of doubt that such a system can remain manageable. If, for example, 15 years hence the number of eligible academic investigators will have trebled, federal agencies must adequately operate a project grant system thrice the size of the present. Nevertheless, this mode of operation is the only means of ensuring, safeguarding, and estimating the quality of these endeavors and it fully warrants whatever efforts will be required.

5) Although some postdoctoral fellows might continue to derive their stipends from research grants, funding through the departmental grants or through an enlarged national fellowship program is much to be desired. In any case, there should be explicit recognition of the fact that it is in the career interest of young investigators, at this stage, to engage in a significant amount of formal teaching. Frequently, this could be done usefully in the very institution in which they are gathering further research experience. Alternatively, there would be great advantage in having these eager and almost completely trained research scientists serve teaching internships at liberal arts colleges or junior colleges within commuting distance. Such experience would be enormously beneficial to apprentice teacher-scientists while ameliorating the current plight of these colleges.

Support of Academic Research by Mission-Oriented Agencies

Of the financial support of fundamental research by the federal government at "educational institutions proper," 85 percent is currently justified in agency budgets by its underlying relevance to their practical missions. Most of public giving, for biomedical research for example, is similarly oriented. But the academic institutions in which research is performed are not equivalently mission-oriented; universities are organized in terms of their educational functions. Accordingly, there is a mismatch between the requirements for success in much of mission-oriented research and the disciplinary structure of the university. Whereas the historical unit of academic research activity is the professor and his coterie of students, fellows, and technicians, successful "directed" mission-oriented research increasingly demands the concerted effort of a multidisciplinary team. Attempts to finance academic research by addressing the specific problems of the mission-oriented agencies could distort the intellectual structure of the university, and pose a threat both to the pursuit of imaginative independent research and to the education of the very scientists required to man such multidisciplinary teams. Hence, most research in academic disciplinary departments, regardless of the source of supporting funds, should continue to consist of individual efforts. In practice, this would probably mean that NSF and NIH would contribute the bulk of the federal funds in support of academic research. Since the leading edges of science are frequently at the interfaces between disciplines, such a policy should not be so misapplied as to deter spontaneous alliances arising out of the mutual scientific interests of faculty members. Concomitantly, however, the university might well encourage the parallel development, on campus or in reasonable proximity, of appropriately organized contract centers for mission-oriented directed or applied research. Such an arrangement could safeguard to the mission agencies the principal advantage of current practice which is frequent contact between agency scientists and those of academia, thereby helping to keep the former *au courant* and occasionally interesting the latter in a fundamental problem of relevance to the agency mission.

On the Magnitude of the National Scientific Endeavor

If one accepts as a national goal provision of the maximum education for which each student is qualified, then the number of prospective graduate students becomes a valid criterion for projection of future budgets. Our national history indicates that there have always been those who opposed an extension of the educational system—yet each such extension resulted in an expanded economy and improvement in the quality of life for the nation generally. There is no apparent reason for limiting this process and it is doubtful that the question, "Who will employ all those scientists?" is meaningful. Rather, it seems likely that, in this instance, supply engenders demand. And if, one day, a few more teachers with Ph.D.'s are found on the faculties of high schools, this scarcely seems objectionable. Meanwhile, there is a need to consider development of programs leading to an advanced degree without the requirement for a significant experience in independent research.

Unless our patterns of national life change drastically, the projections of future graduate enrollments by the Office of Education indicate a doubling of the present graduate student population by about 1976. If these projections are borne out, in a general way, they establish the future minimal dimensions of the graduate education–research enterprise. In this light, the frequently cited proposal of a gross increase in funding of about 15 percent per year for university-based science seems a reasonable match to opportunity and need which allows for the growth of the graduate population, for the cost of increased sophistication of research itself, and provides a margin for inflation, but probably seriously underestimates future costs of computer usage. Although an annual 15-percent increment affords opportunity for many types of specialized undertaking, it should be regarded as an umbrella beneath which lies, in the main, the aggregate of "small science." Specific opportunities which will require large-scale capitalization and operational costs will undoubtedly present themselves; if these are justified on scientific grounds, they need not be restricted in any one year to that which is possible within the umbrella.

Obviously, it will be necessary to construct a physical plant commensurate with such growth. In view of the long lead time required, current levels of funding for this purpose are seriously inadequate, and each year we fall further behind. Moreover, federal agencies and Congress must agree to more generous matching formulae than those in current use if these goals are to be attained.

It is no longer necessary to persuade either the public or its elected representatives that federal support of fundamental research is, in principle, in the national interest. But it will ever be necessary to justify the *size* of that effort. Surely, a central parameter for estimating the magnitude of the academic research–graduate education component must be the dimensions of the graduate student population. Federal expenditures for fundamental research outside the academic setting should be determined by the continuing needs of the mission agencies, and justified accordingly.

As this growth proceeds, it will give impetus to the strengthening of academic science across the country. Although the size of an individual university knows no fixed maximum, it probably does have an optimum. As the established institutions become saturated, well-qualified students will, increasingly, seek graduate and postdoctoral experience elsewhere—at the scientifically lesser universities already in being, or at new universities, particu-

larly the new urban public universities. This driving force will generate the opportunity to upgrade the science activities of these universities and they should be provided with the requisite resources in faculty and physical plant. Although, admittedly, this is a painstaking, slow process, it must certainly represent the most effective, rational means to achieve "more equitable geographic distribution of federal funds."

Sources of Funds for the National Science Enterprise

In view of the broad impact of science on all aspects of society, of the magnitude of the enterprise, of the institutionalized forms of science, and the intrinsic cost of individual research projects, it seems unlikely that the role of the federal government as the major patron of science will be challenged in the foreseeable future. Even the minimum unit package of support has become a sum so substantial that few other potential sources may be seriously considered. This prospect is also evident from the fact that the nation's largest philanthropic foundations have abandoned to the public purse the support of this vital enterprise. If the general grant philosophy presented above is to be implemented, a serious challenge will be posed to the pluralistic support mechanisms of the moment, particularly to the roles of the mission agencies on the academic scene. Inevitably, the National Science Foundation, the Endowment for the Humanities, and the Office of Education must assume ever larger shares of the responsibility for academic research-education and for the welfare of academic institutions, while a special role is reserved to the National Institutes of Health in the field of biomedical research-education. Indeed, although the time is not yet at hand, it appears to be increasingly logical to consider regrouping these agencies into a single Department of Science and Education.

Meanwhile, the other mission agencies should foster specific centers for relevant fundamental research, associated with universities, rather than broad institutional programs directed at academia. The fact that agencies such as DOD, AEC, and NASA require large numbers of trained scientists and engineers, and have large total budgets, should no longer be used as an argument in favor of their support of graduate education, broadly conceived. The same Congress that votes their budgets can also provide direct support of graduate education–academic research in its own right in the budget of an appropriate agency. However, all agencies should develop uniform guidelines and minimize the number of individual types of programs. The present federal grants structure evolved rapidly as the consequence of many actions taken by both the Congress and the Agency administrators. This structure has repeatedly been altered or extended by imaginative bureaucrats who have frequently been more perceptive of academic needs and more zealously mindful of academic autonomy than have those in the universities. But now that the federal government has accepted responsibility in large part for the science–graduate education endeavor, programs for its support should be relatively few in number, simple, and forthright.

When our nation again knows peace, the academic research endeavor may hope to find stable and much enlarged support. There are few who challenge that the R & D effort is essential to solution of some of the more pressing problems of our society. The great social revolution of our times was begotten by the previous successes of the industrial, scientific, and agricultural revolutions. The condition of our nation at the turn of the next century will be determined by the research accomplishments of the few years which remain.

Note

This article is adapted from a statement presented at a symposium at the annual meeting of the National Research Council, Washington, 11 March 1967. In preparing this statement, the author has drawn heavily upon his experience as a member of the National Science Board, the President's Science Advisory Committee, and the National Advisory Council for Health Research Resources, but the views expressed are not necessarily those of these official bodies.

NEWS AND COMMENT

The SST and the Government: Critics Shout into a Vacuum

The construction of a United States Supersonic Transport (SST) has grown from small beginnings to an immense enterprise. Before the first production model rolls off the assembly line in 1974, the project's cost will have reached at least $4.5 billion. Each SST will sell for no less than $40 million, more than five times the cost of today's subsonic commercial craft. The airlines will receive a sleek and impressive plane for their money. More than 300 feet long, the SST will carry 280 passengers at 1800 miles an hour. The plane's planners have repeatedly said that the SST represents a new family of commercial aircraft and that its introduction is as significant a step as the shift from prop planes to subsonic jets. There is more to this claim than public relations rhetoric.

Not everyone, however, thinks the SST is a blessing. The plane flies fast, but at supersonic speeds it creates a thunderous sonic boom that people in a 50- to 60-mile path below the plane will hear. In addition, building the SST is a project too big even for the enormous aircraft industry, and the government is financing most of the development and prototype costs, now estimated at more than $1.4 billion. Critics ask not only whether the government should get into the noise-making business but also whether so much money should go to support speed when taxes are about to rise and when many domestic programs are facing an austere future.

The SST program rests on assumptions which ignore such abstract objections. The project was born in the early 1960's when many key problems, including the sonic boom, were apparent; the pressures to build the plane overwhelmed these difficulties. Time has swelled the number of opponents, sharpened their criticism, and added