THE NATIONAL SCIENCE FOUNDATION

Statement by

PHILIP HANDLER
President
National Academy of Sciences

before the

Subcommittee on Science, Research and Technology
Committee on Science and Technology
House of Representatives

17 May 1979

Mr. Chairman, Members of the Subcommittee: It is a pleasure and a privilege to appear before you to present some *personal* views concerning the role of the National Science Foundation in our national life and the manner in which the Foundation functions.

I should start by indicating that, after service on a number of peer review panels and a Divisional Committee of the Foundation, I was for 12 years a member of the National Science Board including two years as its vice-chairman and four years its chairman. But that service terminated five years ago; hence, I cannot claim intimate knowledge of the affairs or internal operations of the Foundation at this time. As President of the Academy and Chairman of the National Research Council, I am responsible for the conduct of a group of significant programs supported by the National Science Foundation. And, in that sense, I am currently the head of a grantee organization. However, none of these programs involves direct conduct of scientific research; all are of that character that Judge Sirica so aptly summarized when he described the Academy as "an ally of the government." For example, with the support of the Foundation and, in some measure, as its agent, we manage programs of scientific exchange with East Europe and China, serve as adhering body to international scientific unions, maintain a registry of all persons with research doctoral degrees, manage selection panels for fellowship programs, conduct surveys of the status of scientific fields and represent the U.S. in the International Institute for Applied Systems Analysis. On the other hand, at no time was my own research ever supported by the Foundation. By virtue of my position, however, I am on the receiving end of a great deal of comment from the nation's scientific community with respect to the state of the scientific endeavor, both substantively in diverse areas of science and functionally in terms of the mechanisms for the support and conduct of science. It is out of this experience that I speak today.

The Foundation has been a continually evolving institution. Born in the aftermath of World War II, it was inspired by the book by Vannevar Bush, "Science, The Endless Frontier." In retrospect, what we then regarded as the grand vision offered in that work proved to be remarkably limited as compared with subsequent reality. To be fair, when that report was written atomic nuclei were thought to contain only neutrons and protons, the cell nucleus was a total mystery, no one had yet spoken of "molecular biology," the transistor was yet to be invented, plate tectonics were unknown, oil emerged from the ground in Saudi Arabia at a cost of seven cents a barrel, "sputnik" was an unknown Russian word, and few of us had heard of "ecology " much less pulsars, quasars or black holes. And the man on the moon was a figment of childish imagination.

The Bush report did not even begin to suggest the scale of the national scientific endeavor, built with federal funds, that emerged so rapidly in the '50s and '60s. Accordingly, the original mandates to NSF, deriving from the description in "Science, The Endless Frontier," proved to be far broader than could be implemented with available funds; this was not a handicap to American science because support of large areas of science became the *de facto* responsibilities of the concurrently growing research and development programs of the Defense Department, the Atomic Energy Commission, the National Institutes of Health, the Space Agency and, later, NOAA, to name but a few.

Moreover, the original Act also foresaw significant assignments that never came to pass, such as those which might relate to the national defense, and the requirement that the Foundation exercise a kind of oversight of the entire federal program of research and development. Even now, traces of such responsibilities are to be found in the basic statute. I have no objection to their presence in the Act; they are a reminder of the essential instrumentality of the NSF to our national purpose and confer authority that might, one day, become necessary to the national welfare.

As the Foundation developed, there were expressed diverse views of the role of the Foundation and of its programs. It was simultaneously to be a "balance wheel," the underpinning of the national research endeavor, the specific source of support for important research at disciplinary frontiers, supporter of applied research when that appeared to be desirable, as well as operator of programs intended to strengthen education in science across the land. Given sufficient funds, even now that set of charges is not an excess burden to place upon this instrument of American society.

But built into the Foundation from time zero was a basic conflict as old as the republic—egalitarianism vs. elitism, in this case, selective support of the very best of science. The Science Foundation has never escaped from that crossfire. Throughout its life there have been members of the Board, of the staff, and of its advisory bodies who have understood that, in science, the best is immensely more important than is the next best. Yet the Foundation has never been permitted truly to implement that phrase as its guiding policy. Major private foundations that have at some time supported scientific research in the United States—and most of them have withdrawn, leaving the field largely to the federal government—were always extremely selective, supporting only the very best of science when opportunity afforded. The Science Foundation has, similarly, been instructed by the Congress and the President to support selectively the best proposals that came before it. But, at the same time, there has always been political pressure, again from both the President and the Congress, to assure geographically equitable distribution of the appropriated funds. The latter charge is explicit in the NSF Act. The conflict inherent in this duality of purpose has had several consequences. Let me explain.

The programs in science education have done much to upgrade the quality of education in scientific disciplines in secondary schools across the land. The fellowship programs have been a critical element in the growth and development of our national

cadre of top-flight investigators. The several programs which, over the years, have been utilized to upgrade and renew the qualifications of secondary school science teachers have had impact in virtually every local school system. In no small measure, these programs have made possible our large national R&D enterprise and have significantly contributed to the national level of general scientific literacy.

The political emphasis on geographical distribution in the support of research has occasioned support of modest research activities in a great number of the nation's smaller colleges and universities. A substantial fraction of the funds appropriated to the Foundation for the support of research has been so managed as to find its way to as many as possible of the 435 Congressional Districts containing more than 1,000 colleges and universities in each of which there are departments of biology, physics, chemistry, mathematics, psychology, economics and sociology. Please understand that, in the doing, the operation is not nearly as crass as I made that sound. All grants have been awarded on the basis of peer review. Be assured that the nonsensical, the trivial and the utterly pedestrian have rarely been supported, and, I trust, never knowingly.

However, although there have undoubtedly been significant exceptions, this activity has contributed relatively little—in a direct way—to the growth of scientific knowledge, per se. Its value must be judged for its contribution to the quality of science education in such colleges, by its effectiveness in keeping alive the intellectual interests of the faculty and, thereby, enhancing the quality of science education in these institutions, as well as by its success in attracting undergraduate students into careers in science. Accordingly, I could wish that such activities were supported—as they certainly should be—from a program understood to be valued expressly for its contribution to science education and managed as a program apart. Separation of the management of such a program would permit those responsible for the management of the basic research program, proper, to address the nation's research requirements with what I regard as a somewhat more appropriate management philosophy.

Were it so separated, the Foundation could then be instructed, instead, to conceive of its other responsibility as the adequate, if not generous, support of the very best to come before it in each of the scientific disciplines within its purview. I say that because the responsiveness of the Foundation to the egalitarian political pressures that led to the current manner of utilizing its resources, coupled to the magnitude of the appropriations to the Foundation, has been a genuine handicap to the Foundation as an instrument for supporting the very best of science.

Agencies such as DOD, AEC, NASA, and NIH, for example, have been in position to fund reasonably fully the best of the proposals before them, proceeding down a list, rank-ordered for quality, as far as their resources permit. NSF, far more constrained to distribute its resources broadly, could not operate in that manner. Funded less generously and so constrained, NSF has found it necessary to bargain even with the most successful applicants for support. Proposals for large new instruments, of course, could not be treated in this way. One cannot build half a ship, half a telescope, or half of a Van de Graaff accelerator. And having brought NCAR, Kitt Peak, and the Very Large

Array into existence, the Foundation is committed to a high level of support as long as they remain scientifically productive. In contrast, individual successful applicants whose work is of the kind usually termed "small science," i.e., not tied to some very large and expensive instrument, almost invariably receive significantly less support than requested and for a shorter time, not because the Foundation has judged their requests excessive but to spread the funds as far as they can go. Rarely is the support provided sufficient to permit an established investigator, or a new investigator with an unconventional idea, the full support required in order to exploit his or her potential. NSF encourages each grantee to stroke a single or double into left field, but very rarely provides the means to try for a home run! Thus, although, over the years, NSF has certainly provided partial support for a considerable number of individuals who went on to receive Nobel Prizes, there have been few, if any, Nobel Laureates who received their full research support from NSF, even during this quarter century of American dominance of international science.

To be sure, these circumstances have been far from tragic. The federal government has operated a pluralistic research support system. I hope that it will continue to do so. Grantees insufficiently funded by NSF have found additional support from other agencies. And, while maximizing geographic distribution and stretching their resources as far as possible, NSF staff have never permitted gross distortions of their programs by either process. But neither have they been able to utilize those resources to make the most powerful possible thrust at the frontiers of science. Scientific progress is better served by fully funding 50 first-rate scientists than by half-funding of 100 such scientists. A wise agency would probably give about 60 of them at least 85 percent of what they seem to require, if it but could.

But as I indicated to this Committee some weeks ago when you were conducting hearings relative to the authorization for this year's appropriation to the Foundation, the total amount of money for the support of basic research, from all agencies, falls short by a wide margin of the amount that the system in being could usefully expend to obtain maximum scientific productivity. I will not here repeat my recital of the factors that have contributed to this circumstance. I direct it to your attention because of its direct relevance to the policy which the Congress and the President should have in view in developing future operational guidelines for the National Science Foundation. While the total system was being deliberately expanded—in numbers of scientists, of research-performing institutions, and of dollars—the approach to the support of research at NSF was acceptable. Before the purchasing power of the total federal funds for research plateaued a decade ago, the number of institutions with graduate level and research aspirations approximately doubled; since then the number of potential investigators has doubled again, the intrinsic costs of doing research rose by at least 50-75 percent and an ever increasing fraction of the total funds available has been required to defray institutional indirect costs. It is out of those considerations that I suggest that the dual charge to NSF, both geographic distribution and support of the best of science, be reappraised.

The clock of history cannot be turned back. The rate and nature of scientific progress will surely pace the nation's ability to assure our national security, stimulate the industrial innovation process, protect the environment, assure an energy supply, stimulate agricultural productivity, and enable us to cope with the subtle forms of disease which are now the greatest menaces to the public health. I could not have said that in quite the same way 20 years ago. At that time, our understanding of life processes was so superficial, we could not imagine the beautiful complexity of living organisms or the subtlety of those aberrations which are called disease. And we were almost unconscious of environmental abuse and hazard. The American scientific research endeavor, then, was far larger and more productive than that of the rest of the world; American technological industry was unrivaled; American military technology was in a class apart; each year, new records were being set for yields of cereal grains per acre or per agricultural worker; the prospects for bountiful cheap atomic energy were virtually unchallenged; imported oil was cheap, unlimited in supply and seemingly unnecessary to our economy. None of that is the case today. The scorecard of national success in these matters, tomorrow, is surely going to be determined by whether we provide to our most talented investigators the full support that their efforts require, regardless of the fact that they are not homogeneously distributed among the 50 states.

Accordingly, I would suggest, Mr. Chairman, that in reviewing the programs and management of the NSF, and in considering its basic statutory act, the principal question before you is: What shall the nation expect of the National Science Foundation in the next quarter century? What should be its role? Is the progress of science and attention to our national problems to be the overriding consideration or is geographical distribution of grants? Will the nation look to NSF as a major supporter of the basic research that will make possible future developments in industry, agriculture, energy, mineral resources, materials, and medicine, or is such responsibility to be left largely to the assorted mission agencies whose basic research budgets are always under pressure to accommodate to one or another sense of urgency for immediate applicability? What management philosophy is required to enable the Foundation to fulfill that expectation? You have a right to expect explicit answers from the National Science Board. But, it is not within the authority of the Board, on its own, to adopt and implement the major policy change which may very well be called for.

Over the years there have been repeated expressions of Congressional concern for what has seemed to be "duplication" between the programs of NSF and those of other federal agencies. In my view, this is a synthetic non-problem. I hold it important that NSF support significant fundamental research in all areas and disciplines of science. The fact that, occasionally, project titles may read alike, should not be a cause of concern. Investigators at the leading edges of their fields are quite aware of what their disciplinary colleagues are doing or hope to do. The likelihood of exact duplication is extremely small; in any case, replication is part and parcel of the scientific method. It is only the reproducibility of results which provides credibility in the first instance and

allows subsequent investigators to build upon those results. In important areas of science, it is valuable, perhaps necessary, that several alternative experimental approaches be explored in parallel.

It is unthinkable that the NSF should remain apart from molecular biology, particle physics, solid state physics or synthetic organic chemistry just because these disciplines also find some support in NIH, DOE, DOD, and the Army Research Office, for example. It is, however, imperative that, in allocating its limited resources, the Science Foundation be highly aware of the nature and magnitude of programs in the other agencies. And it is in this sense that the Foundation should serve as a "balance wheel." The alternative form of that statement is to note that, almost by default, the Foundation must serve as lead agency for the support of those areas of science which are not so intimately related to the mission requirements of other agencies that the latter, *ipso facto*, serve as lead agencies. It is out of such considerations that the Foundation has come to be lead agency in such disciplines as systematic biology, ground based astronomy, the basic science aspects of marine biology and oceanography, organic chemistry, mathematics, and sociology.

Such considerations, in at least a general way, are certainly implicit in the annual budget request of the Foundation. From time to time, the Foundation should also make such an analysis explicit; neither I nor anyone else knows how much federal money now supports research in chemistry, for example. If such data were available for all disciplines and sub-disciplines the Foundation's external advisors and the Board could then better direct attention and funds to the areas of greatest current opportunity and excitement and to those areas of greatest immediate relevance to progress in industry, agriculture, medicine, etc. In the future, such analyses might well become part of the Congressionally mandated Five-Year Outlook.

No chapter in the history of the Foundation has been more tempestuous than its support of research in the social sciences. As revealed by a recent Academy study, the NSF, in fact, provides only a very small fraction of all federal support for the social and behavioral sciences. But only NSF has announced that it is in the business of so doing, and only NSF deliberately supports basic social science research of such character that, one day, the social science research of other agencies may be more penetrating, illuminating and reliable. Nor has NSF been particularly bold in this regard. Since the early days there have been various unspoken but nonetheless real taboos—sex, religion, ethnic voting behaviors, for example. And the nation is the poorer for this avoidance of reality. For its part, the Congress remains uncertain of the value of social science and continues to vacillate in this regard. Witness the fate on the House floor of the NSF authorization Bill reported out by this Committee.

When I appeared before you on 6 March, I said, "It is almost a truism that natural science and technology have considerably outstripped knowledge of social processes and their management. One has only to use a series of buzz words to exemplify the problems: population, crime, poverty, alcohol and drug abuse, child and family devel-

opment, education, employment, aging, cities, sex, discrimination, conflict. I would not dare offer an agenda of studies appropriate to these matters. But it is evident that the research agenda in social and behavioral science is shaped and defined by our times. That understanding comes hard and slowly, if at all, reflects not the competence of the investigators but the intrinsic difficulties of these problems, the lack of useful non-human models, and our great reluctance to experiment using our own people as subject. . .

"Surely we must decide whether we are as risk averse as we have behaved in recent years. Are we, collectively, all that concerned about all forms of cancer when only the incidence of cancer of the lung, due to cigarette smoking, has risen in our lifetimes? What are the relative benefits and costs of the interventions on which we have been intent? Have we or have we not been placing a dead hand on the throttle of the economy, seriously affecting productivity and innovation? What shall we expect as the consequence to our national well-being of inflation, our aging population, intractable unemployment levels, markedly increased energy costs? What will be the consequence of the declining faith and trust in our major social institutions, especially government? Is there an optimal level of mistrust? Can we come to terms with the ever tighter economic interdependence of the world economy?

"The list of such questions seems well-nigh endless. Their answers seem imperative to rational national policy. I can offer only the hope that the social and behavioral sciences will find proximate answers in time to help."

Is it not time for an enlightened Congress to declare its willingness to support the development of the admittedly still young social and behavioral sciences so that we may all learn whether they can, in due course, enable us better to deal with some of our most pressing problems? Is it not beneath the dignity of the Congress to play the game of seemingly silly project titles?

There is also a history of Congressional concern for the role of the Foundation in supporting "applied research." Again, I find this concern unwarranted–providing that the Foundation does not set specific applied mission goals for itself, as it has done, occasionally, in the past. I would encourage the first stages of applied research growing out of recent fundamental research, but discourage the Foundation from full-scale programs of applied research directed to stated, applied missions. By that I mean that the NSF should support research in ecology–but environmental protection per se is the responsibility of the EPA. The NSF may very well support research in seismology, in earthquake prediction and on the theoretical basis for earthquake engineering. But it is not the role of NSF to manage a full program intended to culminate in the construction of full-scale demonstration earthquake-resistant structures. The NSF should surely support research in computer science, i.e., appropriate new softwares, as well as in the solid state physics, cryogenics and materials science that may contribute to the hardware of the next generation of large computers–but it should not set out to support the development of such a computer.

I find no difficulty in–indeed I endorse–the support by NSF of research that takes the findings of basic research to the next stage of demonstration of ultimate commercializability–"proof of concept"–particularly when this is done by the investigators who have themselves made the underlying fundamental observations. Thereafter, however, the next stages should be undertaken in industrial laboratories.

There remains, however, a considerable awkwardness. The boundary at which government support of research and development should leave off and commercial research and development should take over is rarely very certain. There may well be a gap which, at this time, goes unfilled, resulting in missed opportunities or needless lags. In previous times, we took a limited view of the role of government and looked largely to industry for the conduct of the entire innovation process. But that was before Germany, Inc., and Japan, Inc., not only competed successfully in international markets but also invaded our domestic market with such success that we now have a negative balance of trade for technology. Hence, we must rethink this position and, probably, agree to a greater role of government in the industrial R&D process. Perhaps this should become a principal role of the Department of Commerce–but that Department does not fill such a role today. Accordingly, I now look much more positively on an expanded role of NSF in this regard, as we live through a time of transition.

In some part, the recent great success of German and Japanese technological industry has arisen from effective marriages of university and industrial laboratories. There are many barriers to such arrangements in our country, and I hope that the Congress will strongly encourage NSF to experiment with alternative arrangements which might break down those barriers without damage to the integrity of the university yet avoiding direct federal subsidy of industrial research.

When I testified before you in March, I was among those who directed your attention to the difficulties arising from declining college enrollments with consequent lack of faculty appointment opportunities for young scientists (or humanists for that matter). Again, the details need not be rehashed at this time. The Science Foundation should be encouraged to be inventive with respect to ameliorating mechanisms that will preserve for the country this generation of young investigators. I do not think that the NSF statute offers any barrier to that process while I do think that NSF was gravely in error in abandoning its postdoctoral fellowship program. But I repeat what I indicated last time: if possible, the inventions should be of temporary character. About 1995, the later consequences of those declining enrollments will be with us in the form of a declining labor pool; for a decade or more, thereafter, the country will know a shortage of scientists and of almost every other form of skilled labor. We should not repeat the kind of error we made in overbuilding university and hospital capacity by now erecting new institutions–or institutes–which probably cannot be staffed two decades hence.

I also directed attention to the confused and difficult relationships between the government and the universities. But that problem extends across all federal research-

supporting agencies and cannot be solved by actions taken by or on behalf of the NSF, alone. It needs central attention at the level of the President, the Office of Management and Budget and the Congress, so I shall say no more here.

The National Science Foundation Act has always stated that "The Foundation shall consist of a National Science Board and a Director"—language equivalent to that used in the charters of privately incorporated foundations and universities. It has been a bone of contention ever since, an irritant, at various times, to the President, the Office of Management and Budget, the Congress and the Foundation's staff. Originally, this description was true in the sense in which it has been true of major foundations whose boards must give express approval to all grants made by these entities. But the funds now annually distributed by the NSF exceed the capital of all but the very largest of the foundations on which it was modeled. During my term of service, the Board, perforce, retreated from this grant approval function, and that retreat was made statutory by the Congress a decade ago. I find rather ironic the current description, in the Act, of those grants for which the Board cannot delegate its approval authority. The provision relates specifically to the dollar magnitude of a given award. Yet, in my experience at the Foundation, it was the grants of largest magnitude which were most carefully justified by the applicants and most penetratingly examined by the staff. Policy problems generally do not arise as some function of the magnitude of a given grant.

Nevertheless, I would not take exception to this limitation on the Director's authority since it does keep the Board in touch with the major granting activities of the Foundation and keeps the staff mindful of this approval function of the Board. While I was Chairman, we instituted a process—perhaps still utilized—wherein the Board would review and approve all proposed grants under a new program to assure that the program was being managed as intended, that the grants being made were, indeed, of the character that had been visualized when the program was planned. When the Board was so satisfied, it delegated its approval authority to the Director. I consider this a useful procedure and a proper role of the Board.

The present situation, however, is anomalous. The Board cannot be held accountable for actions taken under authority it does not have. If the nation is maximally to benefit by the very existence of the Board, I consider it far more desirable that the Board have full approval authority for all grants—and authority to delegate any or all of that authority to the Director as it had done in large part before the current provision was written into law. Only thus can it be held responsible—and be expected to act responsibly.

The functional role of the Board has long since departed from merely that as the ultimate approving body for grant awards. It should function as an antenna, bringing to the highest level of consideration at the Foundation the concerns of the nation, the opportunities and the problems of research-performing institutions. The annual report of the Board is an excellent vehicle for this function. The Board should satisfy itself that the allocation of resources among Foundation programs optimizes the use of *all*

federal funds in support of research and are also wisely deployed to serve the educational function of the Foundation. In these senses, it should truly act as the "National Science Board" rather than as the "Board of the National Science Foundation."

Above all, at the Foundation, the Board serves two principal roles. (1) By its very presence, it maintains the character and integrity of the institution, helping to keep the Foundation's staff accountable to its external constituency, assuring that objective peer review will remain the basis for decision-making within individual programs.

(The importance of peer review seems usually to be misstated. To be sure, it is the basis for decision-making, for choosing among alternative proposals and for weeding out those that should not find approval. But I would guess that the judgments made by an excellent staff, on its own—and NSF *has* an excellent staff—would not depart significantly from those made by peer review. Rather, the principal role of peer review is to serve as the mechanism for the accountability of this entire system to the nation at large. In no other element of the entire federal apparatus does there exist so detailed and so smoothly functioning a mechanism to assure accountability for the *quality* of the enterprise as does peer review in the selection of research grantees by the federal agencies so engaged.)

(2) The other major role of the Board is political. When necessary, the Board can shield the Director and his staff from furious gusts in the winds of political change. There have been such episodes during the tenure of each of the Directors of the Foundation. A wise Board, led by an effective Chairman, can buffer the Foundation against impetuous acts of retribution that can occasionally menace when some minor episode has been magnified out of all proportion.

I shall not speak to the composition of the Board other than to indicate my firm belief that a large fraction of the Board must consist of distinguished working scientists genuinely conversant with the substance of the Foundation's activities. And if my sense of the appropriate future of the Foundation holds, that will be more true than ever.

Mr. Chairman, the scientific enterprise of our country will be even more important to the national welfare tomorrow than it was yesterday. Our national circumstances are changing, and I hope that the National Science Foundation Act will ever allow the Foundation the flexibility to serve the nation as those circumstances warrant.