SCIENCE AT THE BICENTENNIAL

A Report from the Research Community

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

National Science Board/1976

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NATIONAL SCIENCE BOARD

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Report of the National Science Board/1976

National Science Board
National Science Foundation

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LETTER OF TRANSMITTAL

April 30, 1976

My Dear Mr. President:

The National Science Board has the honor of transmitting to you and through you to the Congress its Eighth Annual Report, *Science at the Bicentennial—A Report From the Research Community*. This Report has been prepared in accordance with Section 4(g) of the National Science Foundation Act of 1950, as amended.

In response to an inquiry by the National Science Board, over 600 representatives of the research community in universities, industry, government, and independent research institutes throughout the United States provided their views on conditions affecting research or likely to affect it in the near future. Specifically, they were asked to describe critical issues or problems they believe will decrease the effectiveness of research "unless properly addressed."

The many aspects of those issues or problems identified in the responses are detailed in this Report. Greatest concern centered upon dependability of funding for research, the vitality of the research system, freedom in research choices, and attitudes toward science and technology.

The National Science Board believes the Report points to a need for action, in which government, the scientific community, and the public have a part, in assuring that those concerns are properly addressed.

Respectfully yours,

Norman Hackerman
Chairman, National Science Board

The Honorable
The President of the United States

FOREWORD

Scientific research in the United States has grown up in close relation with other parts of the national life, at once affected by and affecting intellectual, social, and economic developments. An assessment of the present state of the American research enterprise therefore merits inclusion in our national self-accounting at the Bicentennial. This Eighth Report of the National Science Board is offered as part of that accounting.

Specifically, the Report is intended to show what critical problems appear to be developing in the operating research sectors that will decrease the effectiveness of research unless properly addressed. A question to that point was put to broadly-informed persons in the research community. This Report provides the means by which their responses can be made widely known.

The circulation of these views initiates a two-part task. The second part, for which the first is essential, is devising the means by which the critical problems can be "properly addressed" so that any decrease in the effectiveness of research in the United States may be avoided.

The National Science Board undertook this collection of views in response to clear evidence that scientific research, after a period of relative well-being, is today exposed to severe stress. That stress originates in fundamental changes in such matters as age patterns in the population, the availability and distribution of economic resources, and the order of values guiding national directions.

To obtain the views of the research community, the Board sent letters of inquiry to more than 900 persons active in the administration of research, and in some cases in performing research, in its four main sectors: universities, industry, Federal laboratories, and independent research institutes. Management, policy, and the institutional environment for research were designated as the principal areas in which identification of critical issues and problems was sought, but no definite limitations were placed on the possible answers.

The responses provide a rich resource for consideration by the National Science Board and the various readers to whom this Report is addressed: the President, the Congress, the scientific community, and the public.

The National Science Board found two outstanding features emerging from the hundreds of replies. One feature was the commonality of judgment, across all sectors and transcending parochial interests, as to what the major problems are. The second was the intensity of concern about these problems and about the prospects for science in the immediate future.

The principal areas of common concern were these: dependability of funding for research; the maintaining of vitality in the research system; freedom in research; and current attitudes toward science and technology.

This Report contains chapters on each of the four areas of concern. In these chapters the Report relies almost wholly on direct quotation of the respondents, without interpretation. This method reflects the belief of the Board that systematic discussion of the respondents' independent views as given and of additional views still to be sought must be carried out before there can be general agreement on solutions and how best to put them into effect. In the coming months the Board plans to initiate further discussions with the science community and the general public. Regional Forums under the auspices of the Board will be held in different parts of the country. At those meetings, issues of the kind brought out here will be discussed with organizations in science and other public groups, with this Report serving as a basic document.

The commonality of judgment and the intensity of concern which distinguish the responses in this Report give promise that these discussions will be a forceful stimulus for thought and action.

The Board is deeply grateful for the insights contributed by its respondents. Responses were received between midsummer and midautumn 1975. No attempt was made to update those responses which in one detail or another may have been overtaken by developments since then.

ACKNOWLEDGMENTS

The National Science Board has had the assistance of many persons in government, education, and the research community in preparing its Eighth Report. Dr. James J. Zwolenik, Division of Science Resources Studies, National Science Foundation, served as Executive Secretary and Staff Director for the NSB Committee on this Report. Staff work was shared with Dr. Donald E. Buzzelli, Office of Planning and Resources Management, National Science Foundation, while Mr. Frederic W. Collins, Public Information Branch, National Science Foundation, collaborated as an editor and writer. Outside consultants were Prof. Carroll W. Pursell, Jr., Lehigh University, on the history of science in the United States, and Prof. Albert H. Teich, State University of New York at Albany, on Federal laboratories. An indispensable contribution to this study was made by the more than 600 scientists and research administrators throughout the American research community whose thoughtful letters provided most of the material for this Report. Their names are listed in Appendix C.

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RESEARCH IN THE UNITED STATES: A HISTORICAL PERSPECTIVE 1

INTRODUCTION

As the United States counts its assets at the Bicentennial it can include a strong capability in scientific research. From a modest start, a continuity of effort has developed this resource to its present worth.

Through two centuries, that effort has had as one of its main purposes the building of social institutions both public and private for the training of scientists and for performing and supporting research. At the same time effort has been devoted to the necessary task of defining a mutally satisfactory relationship between research and the society within which it proceeds.

Debate as to the terms of that relationship continues, and some of the issues are not fully resolved today: among them, how to insure adequate and stable funding for research; how to maintain the vitality of existing research institutions, particularly by insuring for them a steady supply of competent new people; how to uphold freedom in the conduct of research while drawing upon it to serve national purposes; how to develop an informed understanding and support of research on the part of government and the public. Dominant views on these issues at any given time have had much to do with the development of the structure of research and the level of research capability.

In the twentieth century science has proved its worth to the Nation during two world wars and the pressure of international competition in space, and in so doing strengthened its capabilities. As a sequel in each case, the gains of science were consolidated in organizations, some new, some old, which together formed a new system of research support. During the 1920's, industrial research laboratories and philanthropic foundations took their places alongside universities and government agencies as important contributors to the research enterprise. The period after World War II witnessed the addition of important new science agencies. This was carried further with the opening of the space age. Indeed, this period saw an extensive federalization of the Nation's research establishment.

The history of the first two centuries closes with what many regard as a new crisis, at the moment less coherent than those earlier in this century, and one challenging rather than confirming the prevailing structure for research and its interactions with society. The historical record highlighted in the following pages perhaps gives ground for hope that this crisis will be met by new creative change in the institutions for research and new progress in devising the terms of their relationship to society.

THE BUILDING OF INSTITUTIONS

During the nineteenth century, American scientists were successful in convincing many private and public patrons that science was useful in a very practical sense. In the first decades of the twentieth century, there emerged a system—not exactly matched outside this country—in which new knowledge flowed from laboratory to application. In a Nation growing more industrial, more urban, and more integrated, the rise of graduate universities, research-oriented government bureaus, industrial research laboratories, and nonprofit independent research institutes stimulated and served American society.

Universities

Undergraduate teaching in science had been a part of American college curricula since the Colonial period, but not until the establishment of West Point in 1802 was practical science (other than botany for doctors) taught to people who would presumably use it. In 1824 the Rensselaer Polytechnic Institute became the world's first private engineering college. And in 1847 Eben Norton Horsford returned from work at Liebig's university laboratory in Giessen, Germany to set up what became the Lawrence Scientific School at Harvard. Yale, at about the same time, established its School of Applied Chemistry, which from the beginning combined commercial chemical analysis with teaching. In 1862 the Morrill Act provided each State with a grant of land to establish agricultural and mechanical colleges, and during the post-Civil War period the number of private polytechnic institutes grew rapidly. With the establishment of the Johns Hopkins University in 1876, the full-blown German tradition of pure scientific research and graduate seminars was firmly set in this country, and by World War I most American universities counted research and public service (often defined as the application of research) along with teaching as their special duties. Until the advent of large Federal funds during and after World War II, the pattern of graduate education in science established by Johns Hopkins remained dominant.

Government

Government agencies, some dating back to the early years of the Republic, were by 1902 spending an estimated $11 million for scientific research including what are now called social sciences.[1] New national needs led to new agencies and bureaus. By 1900 the U.S. Department of Agriculture could be looked to for examples of problem-oriented basic research in a government agency. The organic act establishing the new Bureau of Standards in 1901, giving it the responsibility for "the solution of problems which arise in connection with standards," was broad enough in theory to permit both basic and applied research necessary for its mission. The establishment of agencies of this kind tended to legitimize a role for the Federal Government as patron of science. Because they were dependent upon public money, there was strong reason to show that the science they supported was conducive to the public good. In many cases programs served an area of science closely related to significant economic forces in the private sector, and science administrators had to find a balance point between those interests which wanted only that research which would be of immediate use to their industry, and those which wanted only the most basic work to be done so that all firms would have an equal likelihood of finding practical application for the research.

Industry

Industrial research too was increasing during the first decades of the present century. From small beginnings in private analytical laboratories, in the workshops of inventors, and in the troubleshooting of individual consultants to particular firms, this sector grew rapidly. Such laboratories numbered about 375 on the eve of World War I, and 1,600 in 1931.[2] In justifying their costs to shareholders, the

[1] A source for information on government science is A. Hunter Dupree, *Science in the Federal Government: A History of Policies and Activities to 1940* (Cambridge, 1957). For figure cited see p. 295.

[2] A survey of the rise of industrial research is Howard R. Bartlett, "The Development of Industrial Research in the United States," *Research—A National Resource. II—Industrial Research.* Report of the National Research Council to

practical benefits were placed foremost: industrial research, costing a relatively small amount, would yield new and improved industrial products and processes, and resultant profits which would far exceed the initial cost of the research.

Whether the industrial system provided a favorable setting for basic research or whether it should have its principal domicile in universities were issues vigorously discussed in the early years of this century. Among industrial researchers, J. J. Carty of the American Telephone and Telegraph Company thought the universities the better place. Distinguishing between "pure" and "applied" research on the basis of motive (to discover truth in the first instance and to solve problems in the second), Carty maintained that "the contributions of pure science as a whole become of incalculable value to all the industries."

Since no single company could be expected to support work which would benefit its competitors equally with itself, Carty argued, "the natural home of pure science and of pure scientific research is to be found in the university, from which it cannot pass." The problem of financing was, in his mind, to be solved by funds from "those generous and public-spirited men and women who desire to dispose of their wealth in a manner well calculated to advance the welfare of mankind, and it should come from the industries themselves, which owe such a heavy debt to science."[3]

A different approach was taken by Arthur D. Little, in his 1913 presidential address before the American Chemical Society. He declared that because real problems could be as basic, difficult, and interesting as those of pure chemistry, "a constantly rising proportion of our best research is carried on in the laboratories of our great industrial corporations."[4] A significant contribution to the discussion was eventually provided by Nobel awards showing just how fundamental the research in industry could be—to Irving Langmuir of General Electric in 1932 for chemistry,[5] and to Clinton J. Davisson of the Bell Telephone Company in 1937 (with G. P. Thompson, Great Britain) for physics.[6] This work evidenced a link between basic research and the needs of industrial enterprises.

Foundations

In the opening decades of the twentieth century those "generous and public-spirited men and women" of whom Carty spoke were pioneering in another kind of organization destined to play a valuable role in the support of science—the philanthropic foundation. During the nineteenth century, such wealthy patrons had already established colleges and astronomical observatories. By 1900 there had also been set up 18 foundations, and by 1930 there were nearly 300, of which 33 were particularly devoted to the support of scientific research.

In that year Frederick P. Keppel declared that the "foundation's nearest relative" was, "without any question," the university. Indeed, Keppel's own Carnegie Corporation had once been termed a university without students—perhaps the ultimate dream of those science professionals of the late nineteenth century who

the National Resources Planning Board (Washington, December 1940) pp. 17-77.

[3] J. J. Carty, "The Relation of Pure Science to Industrial Research," *Transactions of the American Institute of Electrical Engineers*, **35** (1916), 483, 484, 487.

[4] Arthur D. Little, "Industrial Research in America," *Science*, **38** (Nov. 7, 1913), 648.

[5] The standard history of the General Electric Research Laboratory is Kendall Birr, *Pioneering in Industrial Research: The Story of the General Electric Research Laboratory* (Washington, 1957).

[6] For a standard history of the Bell Telephone Laboratories see: M. D. Fagen (ed.), *History of Engineering and Science in the Bell System, the Early Years (1875-1925)*. Bell Telephone Laboratories, 1975. This is volume I of a contemplated two volume series; or Prescott C. Mahon, *Mission Communications, The Story of Bell Laboratories*, (Murray Hill, N.J., 1975).

hoped to provide for research in its purest form. Like the university the foundations found their responsibility in basic research. "The prosecution of fundamental researches," wrote Keppel, "will remain one of the major opportunities, perhaps the major opportunity, of foundations, so long as they themselves endure."[7] Nearly three decades later it was to be remarked by Robert S. Morison, of the Rockefeller Foundation, that foundation grant-in-aid programs for basic research since about 1925 had "presumably formed the templates" for government grant programs after World War II.[8]

Independent Research Institutes

Since the first half of the nineteenth century, a few institutions had existed which were privately established and endowed, were broadly educational though not actually schools, and which carried on planned research from time to time. In 1830 the Franklin Institute, one of the most important of the so-called mechanics' institutes of the time, established in Philadelphia in 1824, received a grant from the Federal Government to study the causes of steam boiler explosions. That is generally thought to be the first research grant made by the Government to a private scientific institution.

In the twentieth century, a number of other research institutions were founded. In 1915 the Mellon Institute of Industrial Research placed on a permanent basis the Industrial Fellowship Program. This was first conceived in 1906 by Robert Kennedy Duncan, then a professor of industrial chemistry at the University of Kansas. An endowment from the Mellon family enabled the Institute to match suggested research problems with competent scientists willing to undertake their solution. In 1929, thanks to an endowment from Gordon Battelle, a Columbus, Ohio, industrialist, the private and independent Battelle Memorial Institute began work. These were soon followed by others—The Purdue Research Foundation in 1930, the Research Foundation of the Armour Institute of Technology in 1936, and in that same year The Ohio State University Research Foundation.

After World War II, independent research institutes were seen as a reasonable and convenient method of administering funds earmarked for particular research projects. On occasion they were also able to serve as regional facilities through which independent colleges and universities could pool their scientific resources. Before World War II, research problems and funds came predominantly from industry. After the war, they flowed increasingly from the Federal Government.

THE 1920's: SCIENCE SEEKS SUPPORT

During World War I, Government support of the new National Research Council, founded in 1916 as an appendage to the National Academy of Sciences, gave university-based pure research scientists an acquaintance with Federal funding.[9] But support for pure science remained a problem. Studies of the subject were part of the work of President Hoover's Research Committee on Social Trends, which in a 1932 report found a steady deterioration of public interest in basic science accompanied by a corresponding rise of interest in both applied science and its commercial uses.[10]

In a major attempt to build public support for pure science, leaders of the national science establishment sought from 1926 to 1930 to accumulate a National Research Endowment.[11]

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[7] Frederick P. Keppel, *The Foundation: Its Place in American Life* (New York, 1930) pp. 9, 10, 89-90.

[8] Dael Wolfle (ed.), *Symposium on Basic Research*, (Washington, 1959), p. 237.

[9] On the NRC see Daniel J. Kevles, "George Ellery Hale, the First World War, and the Advancement of Science in America," *Isis*, **59** (Winter, 1968), 427-437.

[10] Hornell Hart, "Changing Social Attitudes and Interests," *Recent Social Trends*, I, (New York, 1933), 388-397.

[11] Ronald C. Tobey, *The American Ideology of National Science, 1919-1930* (Pittsburgh, 1971), pp. 199-232.

In support of the campaign, when he was Secretary of Commerce, Mr. Hoover had warned that over the years, "for all the support of pure-science research we have depended upon three sources—that the rest of the world would bear this burden of fundamental discovery for us, that universities would carry it as a by-product of education, and that our men of great benevolence would occasionally endow a Smithsonian or a Carnegie Institution or a Rockefeller Institute. Yet," he continued, "the whole sum which we have available to support pure-science research is less than $10 million a year, with probably less than 4,000 men engaged in it, most of them dividing their time between it and teaching."

To augment this support, which he claimed was actually diminishing, Mr. Hoover called for increased aid from government, from industry, and from private philanthropy. Warning that the Nation must have more basic research if it "would march forward," he called for "more liberal appropriations to our national bureaus for pure-science research instead of the confinement as today of these undertakings to applied-science work." He welcomed "the opportunity to again demonstrate in our Government, our business, and our private citizens the recognition of a responsibility to our people and the Nation greater than that involved in the production of goods or in trading in the market."[12]

THE GREAT DEPRESSION: SEARCH FOR A NEW SYSTEM

The campaign for a National Research Endowment, including appeals to the Nation's large corporations, fell far short of what was hoped for, and early in the Depression the fund-raising effort was dropped.

The Great Depression, with its disastrous deflation and unemployment, put even more financial constraint upon pure science as research budgets in all sectors were reduced. There persisted among many leaders of the Nation's science a fear that Federal subsidy of basic research would subject researchers to political restraints in the form of both dictated goals and uncertain budgets. Now, with other sources so badly pinched by hard times, Mr. Hoover's suggestion that Federal support should be enlarged was taken up once again.

In 1933 and again in 1934 the Science Advisory Board, which had been established by executive order from the White House in a new administration, submitted for the Nation's consideration what it called its Recovery Program of Science Progress. While aiming for the most part at the twin ills of unemployed scientists and unmet social problems, the Board, headed by Karl T. Compton, president of the Massachusetts Institute of Technology, called also for grants in aid of research in basic sciences. "It should not be forgotten," warned the Board, "that back of applied science must be continual progress in pure science. Consequently any well balanced program of research should provide for continued productive activity in the fundamental sciences. It is suggested therefore," the Board concluded, "that some portion of the funds here discussed be made available for such research, with particular consideration of important programs already in progress in institutions, which have had to be dropped or curtailed in the present financial emergency."[13]

At the same time, but in a separate context, Compton echoed the misgivings of many scientists: "I confess," he wrote, "to considerable doubt as to the wisdom of advocating federal support of scientific research . . . If government financial support should carry with it government control of research programs or research workers, or if it should

[12] Herbert Hoover, "The Nation and Science," *Mechanical Engineering*, **49**, No. 2 (1927), 137-138.

[13] See Carroll W. Pursell, Jr., "The Anatomy of a Failure: The Science Advisory Board, 1933-1935." *Proceedings of the American Philosophical Society*, **109** (December, 1965), 342-351.

lead to political influence or lobbying for the distribution of funds, or if any consideration should dictate the administration of funds other than the inherent worth of a project or the capabilities of a scientist, or if the funds should fluctuate considerably in amount with the political fortunes of an administration or the varying ideas of Congress, then government support would probably do more harm than good. . ."[14]

The call for more government research, including basic research, was generally supported by scientists. In 1933 the American Chemical Society, while "recognizing fully the need of and approving drastic economy in all government expenditures," found it, "a duty, as patriotic Americans and scientists, to emphasize the importance of fundamental scientific research to the rehabilitation, progress, and prosperity of nations. . ."[15] The journal *Industrial and Engineering Chemistry* editorially urged that "if you believe in the conduct of fundamental research in the laboratories supported by federal appropriations, then say so in some tangible form where it will do good." Such research, the journal felt, was peculiarly appropriate for government: "Federal laboratories in particular should confine themselves to fundamentals when the result can be generally utilized, and should studiously refrain from undertaking work that can be better done in the industries."[16]

During these New Deal years a number of bills were introduced into the Congress to increase the Federal subsidy to scientific research—none of which received any strong backing from the Administration. In 1934 Representative J. H. Hoeppel of California proposed legislation to establish Federal research fellowships with the goals of supporting unemployed researchers and aiding financially distressed institutions of higher education.[17] An official of the University of California said in support of the bill that his own school, "like many other institutions," was "in the embarrassing position of having to refuse the services of highly desirable research workers on account of lack of funds."[18] Three years later the then Representative (afterward Senator) Jennings Randolph of West Virginia introduced a bill specifically "To aid and promote scientific research of a basic character upon which the inception and development of new industries or the expansion of established industries may be dependent."[19]

Persistent efforts of the National Bureau of Standards to obtain specific authorization for new programs in basic research in chemistry and physics failed also, as did efforts to establish a permanent appropriation for engineering experiment stations.[20] In the Department of Agriculture, however, Secretary Henry A. Wallace was quoted as saying that a "great corps of able men delving into mysteries merely for the love of such delving—we call it pure science—are after all, the chaps who are laying the foundation for the revolutionary practical developments which come maybe a generation later." In this case, more success was apparent. The Bankhead-Jones Act of 1935 not only provided for new funds and facilities for basic research in agriculture, but also, at the insistence of the bill's sponsors in the USDA, gave new flexibility in spending to allow researchers to follow more immediately the developing directions of their work.[21]

[14] Karl T. Compton, "Science and Prosperity," *Science*. **80** (November 2, 1934), 393-394.

[15] Quoted in "Raise Your Voice," *Industrial and Engineering Chemistry*, **25** (May 1933), 477.

[16] "Research at Public Expense," *Industrial and Engineering Chemistry*. **25** (March, 1933), 243.

[17] J.H. Hoeppel to the President, April 21, 1934, Records of the Secretary of Commerce, File 96499, National Archive Record Group 40, on H.R. 6968.

[18] Monroe E. Deutsch commenting on H.R. 6968 to Secretary of Commerce Daniel Roper, March, 9, 1934, *Ibid*.

[19] H.R. 1536, 75th Cong., 1st sess. (January 5, 1937).

[20] See Carroll W. Pursell, Jr., "A Preface to Government Support of Research and Development: Research Legislation and the National Bureau of Standards, 1935-41," *Technology and Culture*. **9** (April, 1968), 145-164.

[21] See Carroll W. Pursell, Jr., "The Administration of Science

Although most of the executive and legislative initiatives toward more scientific research during the 1930's—especially those which contemplated new responsibilities or mechanisms—failed to become either law or policy, the needs of science, and especially of basic research, were thoroughly discussed and weighed. Gradually a trend toward greater Federal support appeared, strengthened by the needs of national defense.

As the *Journal of Applied Physics* noted in 1939, pure research came from four sectors: private laboratories supported by philanthropic endowment, industrial research laboratories, universities, and government agencies. "Little need be said about those laboratories included in the first category," it declared. "Let us hope for more of them. Industrial laboratories are, of course, operated primarily for the profit of their parent companies and gradually the companies are learning that it is for their own good to establish pure research divisions in their laboratories. Much can be done to encourage more research in universities but the place above all others to expect research in pure science is in the governmental laboratories. How can society stand by," it concluded rhetorically, "and watch research on electrons, deuterons and neutrons become so important to everyone without lifting a single finger to see that its public servants include at least a small amount in the Federal and State budgets for research in pure science?"[22]

Whether in the future the Government would simply increase its support of basic research in its own laboratories or do so through grants and contracts to universities and industrial laboratories, its role as a source of funds was increasingly taken for granted. The tenor of the times was accurately summarized by Karl T. Compton, speaking in 1938 at a birthday celebration for a prominent private laboratory. "If present economic and political tendencies continue," he remarked, "I see only one ultimate source of support—the government through taxation for the general public benefit."[23]

In 1940, the year in which the United States began to set up its wartime science establishment, the Nation's research and development budget stood at $345 million. Of this total, $234 million or 68 percent came from private industry, 19 percent from the Federal Government, 9 percent from colleges and universities, and 4 percent from other sources, including private philanthropic endowments. Each of these sectors of American science, having developed separately and serving a somewhat different clientele, expended its own money for its own purposes. The Government was not yet entirely convinced that science (especially basic science) had a high claim upon the tax dollar; industry feared governmental competition in technological innovation; universities feared government domination; and many scientists were still leery of bureaucratic control from Washington.

WORLD WAR II: *De Facto* FEDERALIZATION

The coming of war to Europe changed all of this. To an extent impossible in the previous decade, opportunities were seized and fears overcome. Under the spur of this new crisis, science and the Federal Government came together in a new and closer relationship. During the war years funds for research and development (exclusive of those for atomic energy) averaged $600 million a year, 83 percent of which was provided by the Federal Government. A large part of these funds was funneled through the Office of Scientific Research and Development (OSRD). The men

in the Department of Agriculture, 1933-1940," *Agricultural History*, **42** (July, 1968), 231-240.

[22] "Pure Physics Begets Applied Physics," *Journal of Applied Physics*, **10** (January, 1939), 3.

[23] Remarks were quoted in the *New York Times*, October 8, 1938.

most responsible for the wartime science effort were drawn mainly from the tradition of academic research. Vannevar Bush was former vice president of the Massachusetts Institute of Technology, president of the Carnegie Institution of Washington and chairman of the National Advisory Committee for Aeronautics; James B. Conant was president of Harvard University; and Karl T. Compton was president of the Massachusetts Institute of Technology and former chairman of the now defunct Science Advisory Board. A fourth principal was Frank B. Jewett, president of the National Academy of Sciences and the director of Bell Telephone Laboratories.

A fundamental decision of OSRD was that its war effort should be carried on with as little disruption as possible of the existing scientific structure. This meant that OSRD would act to coordinate and stimulate rather than rearrange scientific activities. Through the use of carefully worked out contracts, OSRD concentrated work in major scientific institutions and was thus able to get work underway almost immediately. One consequence of this system was that the best men and the best equipped laboratories were able to make a maximum contribution to the technical problems of the war.

Another consequence was that the strong gained strength. Two hundred educational institutions between 1941 and 1944 received a total of $235 million in research contracts—but 19 universities got three-fourths of it. Two thousand industrial firms received almost $1 billion in research contracts—but fewer than 100 firms got over half of it. Bell Laboratories had $200,000 worth of government contracts in 1939, and this accounted for a mere one percent of the laboratory's activities. By 1944 Bell's work for the Government represented 81.5 percent of its activities, and amounted to $56 million.[24] The contract system got the Government's work done and vastly increased the funding available for industrial and university scientists—but these new funds were heavily concentrated in the largest and most prestigious institutions.

It is hardly possible to trace the fate of basic research during the war. Obviously, the Nation's research and development effort was concentrated on making practical application of knowledge already at hand. The Manhattan District, organized to bring the atomic bomb into being, was an exemplary model of effort of this sort. So heavy was the reliance on previous basic research that the Department of Defense in the mid-1960's reported that its weapons at that time were still based upon that "organized body of physical science extant in 1930."[25] At the same time, not all American scientists were wholly engaged in the war effort and in some fields, such as astronomy, geology, and biology (as opposed to physics and chemistry), the involvement was relatively slight.

POSTWAR PLANNING: CREATING A NEW SYSTEM FOR SCIENCE

As early as 1943 scientists, military men, and civilian administrators within the Government began to plan for the extension of governmental responsibility for the funding of science into the postwar period, using the crisis-tested grant and contract devices. Their motives were varied. Within the Department of the Navy a small group of reserve officers laid plans for establishing an Office of Naval Research to keep the fleet abreast of developing science and technology.[26] Within the Army Air Corps such planners as General Lauris Norstad dreamed of increased service contact with university-based scientists in order to stimulate both scientific research and an active goodwill

[24] U.S. Congress, Senate, Subcommittee on War Mobilization, Report, "The Government's Wartime Research and Development, 1940-44; Part II—Findings and Recommendations," 79th Cong., 1st sess. (1945), pp. 20-22.

[25] Quoted in *Science*, **154** (November 18, 1966), 872.

[26] See "The Evolution of the Office of Naval Research," *Physics Today*, **14** (August, 1961), 30-35.

toward the military.[27] Scientists at work on wartime projects were anxious to return to their academic posts but hopeful of continuing to receive there the Federal support to which they had grown accustomed. And some reformers, both within the Government and within the community of science, were anxious to use the funds and flexibility of wartime for the peacetime benefit of science and its service to the Nation.

Two specific plans for organizing Federal support for postwar science emerged during the last months of the war. The first was legislation proposed by Senator Harley M. Kilgore after 2 years of hearings and consultations with leading scientists. According to his plan, a National Science Foundation would be established which would supervise the disposal of Government funds in three large areas of concern: national defense, health and medical care, and "the advancement of the basic sciences."[28]

The second plan was that of Vannevar Bush, and was based both on his wartime experience with OSRD and his own conception of how science should be organized. In his report of July 1945, entitled *Science, the Endless Frontier*, (requested by President Roosevelt but received by President Truman), Bush proposed the setting up of a National Research Foundation organized into five divisions corresponding to major areas of national need: medical research, the natural sciences, national defense, scientific personnel and education, and publication and scientific collaboration.[29] On the subject of basic research, Bush stressed that it "leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. . . Today, it is truer than ever that basic research is the pacemaker of technological progress. . . A nation which depends upon others for its new basic scientific knowledge will be slow in its industrial progress and weak in its competitive position in world trade, regardless of its mechanical skill."[30] The long war and intensive research and development effort had, in the view of many, seriously retarded the growth of fundamental science. In the past, according to this belief, the United States had relied heavily upon European scientists, particularly those of Germany, to supply this need for it. Now, with Europe prostrate, there seemed no choice but to make the Nation self-sufficient in this essential resource.

A bill based on Bush's plan was introduced by Senator Warren G. Magnuson of Washington on the same day that *Science, the Endless Frontier* was released to the public.

Although superficially similar, the Kilgore and Bush plans for postwar science were formed from very different perceptions of what was best for both science and the Nation at large. Four major areas of conflict were obvious. They could be summed up as follows:

1. Whether the social sciences should be included in the subsidy (Kilgore thought so, Bush did not);
2. Whether funds should be distributed to centers and individuals of proven excellence, or should be distributed more according to the traditional geographical pattern (Bush argued for excellence as defined by peer groups, Kilgore for a greater concern for improving those which fell short of that goal);
3. Whether scientists should have exclusive jurisdiction over the spending of Federal money or should be held politically responsible (Kilgore emphasized responsibility

[27] Perry McCoy Smith, *The Air Force Plans for Peace, 1943-1945* (Baltimore, 1970), p. 110.
[28] See *Technological Mobilization*, I. Hearings before the Subcommittee of the Committee on Military Affairs, U.S. Senate, 77th Cong., 2nd sess. (1942), pp. 1-3.
[29] Vannevar Bush, *Science—the Endless Frontier*. A Report to the President on a Program for Postwar Scientific Research, July 1945. Reprinted July 1960 by the National Science Foundation (Washington, 1960).
[30] *Ibid.*, pp. 17-18 (July 1960).

through the channel of presidential appointment of the director while Bush sought to isolate science from possible Government interference);

4. Whether patents resulting from research should be the property of the Government or of the discoverer (on this count Kilgore argued that research done at the taxpayers' expense should be freely available, whereas Bush argued that discoveries should usually remain the property of those who made them).

The controversy over these points, particularly that involving presidential appointment of the director, delayed the establishment of the proposed foundation for five years, from 1945 to 1950.[31]

In the meantime, large segments of the Nation's research efforts were being organized under independent agencies, complicating the eventual task of coordination. The vast potential of atomic physics, not yet publicly known when Bush and Kilgore reported their plans, was dramatically brought to the public's attention in August 1945 with the dropping of an atomic bomb on Hiroshima, and had to be addressed immediately. The Atomic Energy Commission was established in 1946 as a new agency with a mission that demanded the exercise of concern and initiative in all five of the areas that had been outlined by Bush as the responsibility of the contemplated National Research Foundation. A similar situation developed when the National Institutes of Health, a small agency with vast paper authority, successfully bid in 1945 to take over the unfinished medical research of the Office of Scientific Research and Development.

Within the Navy Department, the establishment of the Office of Naval Research in 1946 provided a military analog to the yet-to-be-formed National Science Foundation. In 1948 the director of the Physical Sciences Division of ONR wrote that "All of us, both officers and civilians in ONR, feel that we are engaged in a very important experiment, investment in basic research. This experiment," he continued, "has two aspects. The first is continuing the relationship developed during the war between scientists on the one hand and the Naval officers on the other, which has had a profound effect on naval thinking and procedure. The second is the support of basic research on a broad and comprehensive scale by the Federal Government." With justifiable pride he claimed that "whatever the future may bring, the Office of Naval Research has helped to keep alive basic research in this country for the past 3 years, stepping in when there was no one else able to carry the burden."[32]

In the postwar years few sources of support seemed so reliable as the military establishment, and while the problem of secrecy was found in many areas of weapons research, the very definition of basic research argued against any such need. Indeed, ONR was proud that in 1946, "of the five hundred university projects in the Physical Sciences Division, only three carry security classification."[33]

Surveying this new and uncoordinated science establishment, The President's Scientific Research Board, chaired by John R. Steelman, declared in 1947 "that, as a Nation, we [should] increase our annual expenditures for research and development as rapidly as we can expand facilities and increase trained manpower. By 1957," it urged, "we should be devoting at least one percent of our national income to research and development in the universities, industry, and the Government."[34] The 1957 share was in fact, 2.7 percent.

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[31] For a recent discussion see J. Merton England, "Dr. Bush Writes a Report: Science the Endless Frontier," *Science*. **191** (9 January 1976), 41-47.

[32] Emmanuel R. Piore, "Investment in Basic Research," *Physics Today*, **1** (November, 1948), 6-9.

[33] *Ibid.*, 8.

[34] *Science and Public Policy. Vol. I: A Program for the Nation.* A Report to the President by John R. Steelman, Chairman, The President's Scientific Research Board (August 27, 1947), pp. 4-5, 6, 28.

Specifically, the Steelman Committee recommended "that heavier emphasis be placed upon basic research and upon medical research in our national research and development budget. Expenditures for basic research should be quadrupled and those for health and medical research tripled in the next decade, while total research and development expenditures should be doubled." In addition, it emphasized that "a National Science Foundation [should] be established to make grants in support of basic research. . ." Although the committee realized that "in-government research and development programs" contained significant basic research components, it argued that "the bulk of the expansion must come in the universities and colleges and be financed by Federal funds." It contemplated a Federal research budget of $2,240 million by the year 1957, 20 percent of which would be earmarked for basic research, most of which would be carried out through grants and contracts. Actual Federal budget R&D obligations for FY 1957 were $3,932 million. Of this total, 6.7 percent was directed to basic research.

NATIONAL SCIENCE FOUNDATION

The eventual establishment of an independent National Science Foundation in 1950 went far towards answering the call of the Steelman Committee. The several areas of greatest controversy over the years were individually solved in the following manner:

1. In the eventual legislation, the social sciences were, by implication, eligible for support, although such support was not mandated;
2. Funds were to be distributed on the basis of scientific merit, but with respect to geographical distribution the Foundation was enjoined "to avoid undue concentration";
3. The Foundation director and the members of the governing National Science Board were to be appointed by the President;
4. Flexible patent policy would allow patents to be retained by those doing the research.

Despite the new National Science Foundation's broad mandate, the actual field within which it could operate was severely limited. The vast fields of medical, nuclear, and defense research were already covered by vigorous programs located in other Federal agencies. In attempting to summarize this diverse Federal activity, the Commission on Organization of the Executive Branch of the Government (the so-called Hoover Commission) noted in 1955 that some 29 different Federal agencies would participate in spending a proposed fiscal 1956 research and development budget of $2,400 million.[35]

MILITARY SUPPORT OF BASIC RESEARCH

The support of basic research by the military services was and continued to be a source of diverse problems. In 1948 the Director of the Physical Sciences Division of ONR pointed to the "need for a National Science Foundation" but at the same time insisted that "the experiences and operations of ONR do indicate that the National Science Foundation should not be the sole government agency engaged in basic research. The ONR," he added, "has been careful not to become the only naval activity engaged in basic research, because giving authorization to a single group has certain dangers found to be inherent in monopolies. . . ."[36] This principle was widely approved among those agencies who wanted their own basic research programs, and found support as well on its merits.

During these same years, for example, the Air Force set up its own basic research agency, the

[35] *Research and Development in the Government*. A Report to the Congress by the [Hoover] Commission on Organization of the Executive Branch of the Government (May, 1955), pp. xi, xii, 50, 47.

[36] Piore, 9.

Air Force Office of Scientific Research. As its historian has written, "That something was done in the end, however, was due less to the inner appeal of basic research than to circumstances. Basic research found a niche for itself in the Air Force during a general organizational upheaval of the Air Force's R&D activities" brought on by dissatisfaction with the Air Force's technological arm, and "the thrust of reform of Air Force technology possessed enough momentum to carry basic research with it." The director of the new AFOSR knew that basic research as such had little appeal and deliberately kept his early budget requests low. In this way he hoped to avoid those large expansions and cuts which made the budgeting of research so unpredictable.[37]

The legislation dedicating NSF to the promotion of basic research raised questions as to the role of AFOSR and that of other such agencies. In 1954, however, the White House issued Executive Order No. 10521 on the Administration of Scientific Research. This document appeared to strengthen the part of NSF in the support of basic research in the Government, and caused some concern in AFOSR. In a response which incidentally highlighted the difficulty of defining "basic" research with any precision, AFOSR simply redefined all its basic research in terms of "exploratory" and "supporting" research. As its historian noted, "any and all line items that smacked of ivy and ivory towers were blotted out. In their place arose such categories as electronics, materials, propulsion, and what have you."[38]

The need felt by AFOSR to do basic research—and to disguise it as "applied"—underscored a continuing uncertainty as to the real position of science *vis-a-vis* society. As Warren Weaver wrote in his preface to a *Symposium on Basic Research* of the American Association for the Advancement of Science and cosponsors (1959), everyone was in favor of science "but what is important about science; what science really is; what scientific activities are 'practical' and what visionary and presumably lacking in significance; what kind and amount of support society ought to furnish to scientists; what balance there should be between the support of *basic science*—the untrammeled search for new knowledge for its own sake—and of *applied science*—the search for and the use of knowledge specifically needed for recognized practical objectives; these are puzzling and unanswered questions."[39] The papers delivered at the symposium itself underscored the fundamental conflict: despite Weaver's definition of basic research as "the untrammeled search for new knowledge for its own sake," the symposium resolved into an attempt to demonstrate that it was to be supported by the public not for its own sake but for the sake of improved technology.

While, as Weaver pointed out, the relationship between science and government was still far from being clearly defined, that part of the Federal budget that could be classified under the heading of R&D grew rapidly during the 1955-65 period.[40] In 1955 the Government research and development commitment amounted to $2,744.7 million (including R&D plant). Of this total $2,084.2 million was obligated by the Department of Defense and another $372.9 million by the Atomic Energy Commission. The budget of the Department of Health, Education and Welfare (including the National Institutes of Health) was $70.9 million. The budget of NSF stood at only $10.3 million. Just 10 years later, in 1965, total obligations for research and development,

[37] Nick A. Komons, *Science and the Air Force: A History of the Air Force Office of Scientific Research* (Arlington, 1966), pp. 13, 52.

[38] *Ibid.*, p. 69.

[39] Wolfle (ed.), xi.

[40] All statistical data, unless referenced to specific documents, are from *Science Indicators—1974*. Report of the National Science Board, 1975 (Washington, 1975) or from *Federal Funds for Research, Development, and Other Scientific Activities* publications of the National Science Foundation.

including R&D plant, had risen to $15,745.9 million (a more than five-fold increase in the decade), of which the DOD obligated $6,865.0 million and a relative newcomer to the science establishment, the National Aeronautics and Space Administration (NASA), accounted for $5,481.9 million. AEC showed $1,539.7 million, HEW had grown to $970.5 million, and NSF had risen to $275.4 million. Of the Federal R&D total of nearly $15,000 million (R&D plant excluded) some 8 percent went to universities, another 4 percent to contract research centers at universities, 21 percent to Federal intramural laboratories, and the chief share, 62 percent, to private industry. The remaining performers, mainly nonprofit institutions, took 5 percent. A closer look at the funds earmarked for university research in 1965, shows that 40 percent came from HEW, 24 percent from DOD, 12 percent from NSF, 10 percent from NASA, 6 percent from AEC, and 5 percent from USDA.

THE 1960's: A MATURE AND PROSPEROUS SYSTEM OF SUPPORT

The orbiting of Sputnik by the Soviet Union in 1957 provided both a jolt to complacency and a powerful stimulus to action to enhance the Nation's capabilities in science and technology. In 1958 the new President's Science Advisory Committee (PSAC) reported that "this year the U.S. Government will spend over $5 billion on research, engineering and development, substantially more than it spent in the entire four decades 1900-1939—and more than the total Federal budget of a generation ago." In part as a result of this massive funding, "in less than a generation, the United States has wrested scientific leadership from its birthplace, Europe, and since 1945 over half of all Nobel prizes in the sciences have been awarded to Americans. The Federal Government has played an important role in this achievement."[41]

[41] *Strengthening American Science*, A Report to the President's Science Advisory Committee (Washington, 1958), pp. 1,3.

The coming of the Kennedy years witnessed an even greater flow of funds and optimism into the scientific community. Shortly before his death in 1963 President Kennedy gave an address before the National Academy of Sciences on "A Century of Scientific Conquest." Praising both the growing support of basic research and the closer links between science and public policy, he celebrated the fact that "we move toward a new era in which science can fulfill its creative promise and help bring into existence the happiest society the world has ever known."[42]

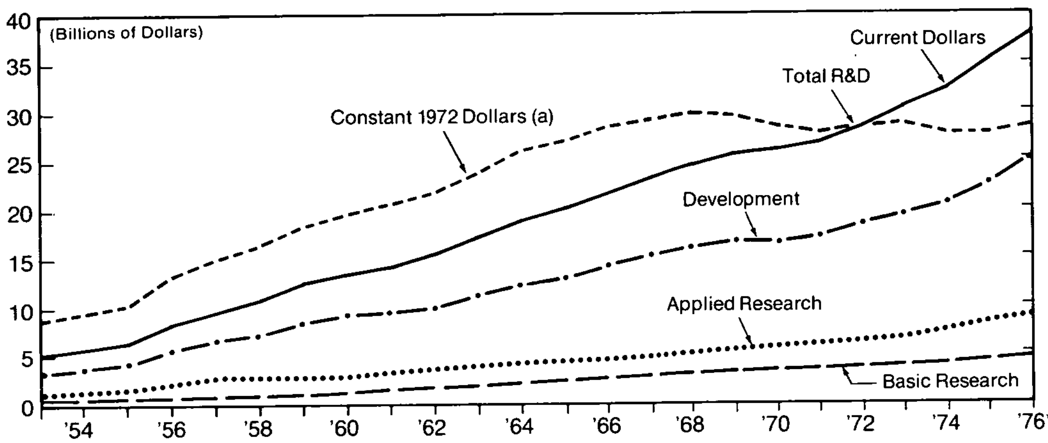
Whether that goal was a realistic one, it fittingly keynoted the euphoria of science in the 1960's. Whether one looks at total Federal spending for research and development (up from $9.3 billion in 1961 to $14.8 billion in 1970), total national spending on R&D (up from $14.3 billion in 1961 to $26.0 billion in 1970), Federal investment in R&D plant above and remaining above half a billion dollars annually after 1960, the number of institutions granting doctorates in science and engineering (up from 162 in 1962-63 to 229 in 1970-71),[43] or the number of doctorates earned in science and engineering (8,055 in 1962-63 and 18,466 in 1970-71)—the story seemed always one of phenomenal growth. The result of this massive spending was a scientific capability with new facilities, new practitioners, and new expectations of support. There were, however, subsurface counter trends, developing into mismatches between resources and claimants. Unforeseen disturbances lay ahead.

CHARACTERISTICS OF THE SYSTEM

This large research establishment, as it flourished in the mid-1960's, had several salient features. *First*, it was heavily dependent upon

[42] John F. Kennedy, "A Century of Scientific Conquest," in *The Scientific Endeavor: Centennial Celebration of the National Academy of Sciences* (New York, 1965), p. 318.
[43] *Science Indicators—1972*. Report of the National Science Board, 1973 (Washington, 1973), pp. 108-09, 115, 135, 136.

Figure 1-1. National R&D Expenditures by Character of Work, 1953-76



*1975, 1976 estimated.

(a) Based on the GNP Implicit Price Deflator. Source: National Science Foundation.

Federal funds. Even before the sixties, over half of the funds for both basic and applied research carried out in universities came from the Federal Government. *Second*, the bulk of these funds came from agencies tied directly to U.S. international competition with the Soviet Union (DOD, AEC, NASA). *Third*, except for the budgeting process carried on in the Executive Branch, the system was not effectively coordinated or integrated by any science policy-making body. And *fourth*, and perhaps most importantly, it was a system which had proven itself acceptable to both government agencies and to nongovernmental scientists. The problems which arose over distribution of funds between regions, disciplines, institutions, and individuals were partly smoothed over by rapidly expanding budgets and the fact that most agencies relied heavily upon peer-group evaluation by panels of established scientists. Finally, the total national expenditure, including that of the private sector, for research and development was growing faster than the gross national product. In 1953-54 R&D equalled about 1½ percent of the GNP; by 1961-62 it equalled almost 3 percent.

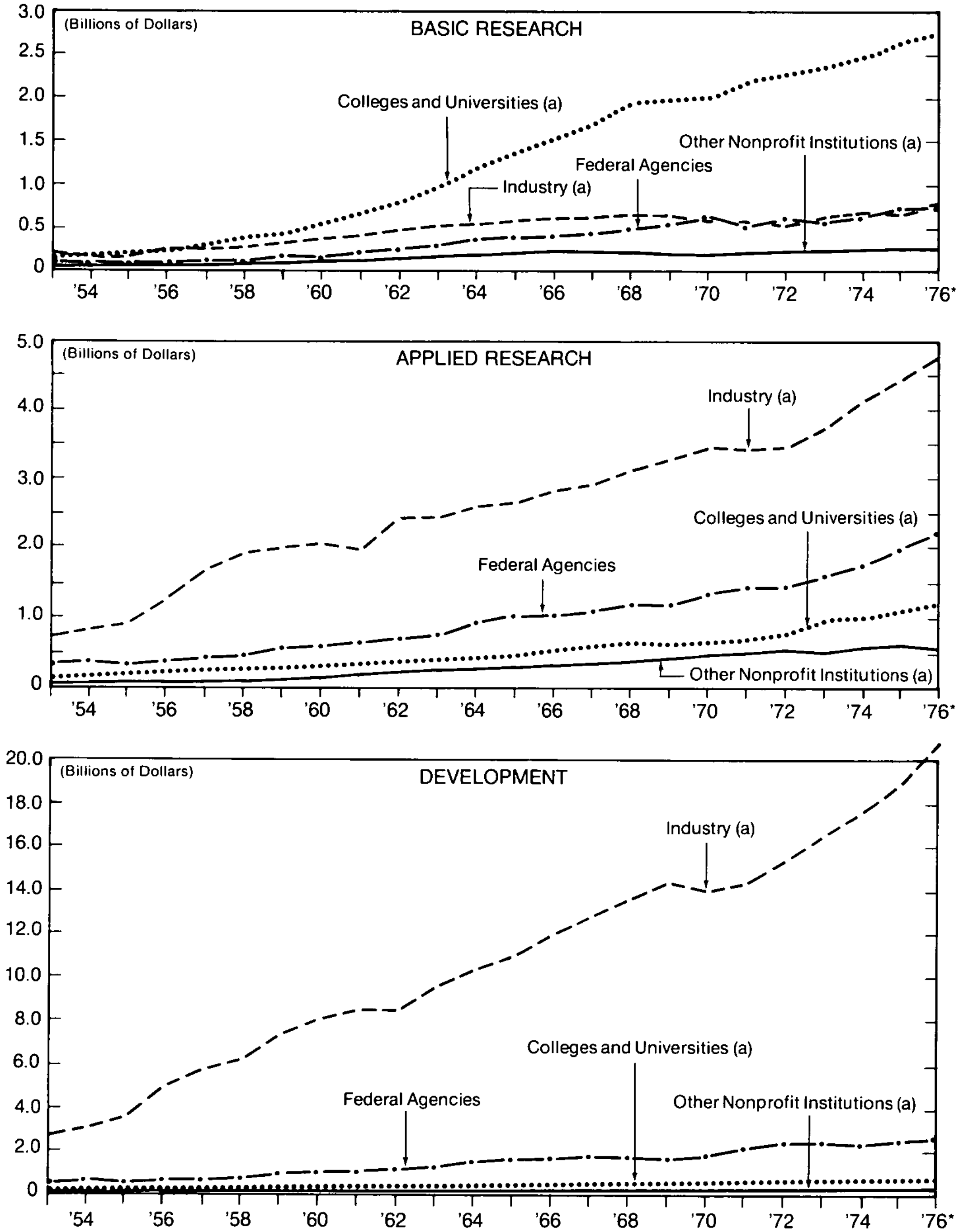
By the mid-1960's, it was clear that although the total national R&D effort was growing, its distribution had settled into a pattern, justified by arguments which had changed little from the prewar period. Most R&D money (two-thirds) went for development, and the vast majority of that was performed by private industry. (See Figures 1-1 and 1-2). More than one-fifth of R&D funds went for applied research with, again, private industry doing most of the work. Finally about one-eighth of the funds went for basic research, half of which was done by colleges and universities and their affliated contract research centers, almost one-fourth of which was carried on by private industry, one-sixth by Federal agencies directly and less than one-tenth by nonprofit institutions exclusive of universities and colleges. Except in the case of private industry, the Government paid the bulk of the money for basic research performance.

CHALLENGES TO THE SYSTEM

Forebodings about the future of the system had been sensed early in the decade. Whether from a distrust of good times or a shrewd reading of the political winds, Philip H. Abelson warned in 1963 that "my guess is that the honeymoon is about to end and that there could be trouble ahead."[44] One source of concern was

[44] *Science*, **139** (January 25, 1963), 305.

Figure 1-2. National R&D Expenditures by Character of Work and Performer, 1953-76



*1975, 1976 estimated.

(a) Includes Associated Federally Funded Research and Development Centers.

Source: National Science Foundation.

the impact that large Federal subsidies were having upon the Nation's institutions of higher education. In 1959 Charles V. Kidd published an influential study of *American Universities and Federal Research,* the thesis of which was "that large-scale Federal financing of research has set in motion irreversible forces that are affecting the nature of universities, altering their capacity to teach, changing their financial status, modifying the character of parts of the Federal administrative structure, establishing new political relations, and changing the way research itself is organized."[45] The expansion of Federal R&D following Sputnik, especially through creation of the National Aeronautics and Space Administration and the National Defense Education Act, greatly increased Federal R&D spending. At the end of the decade, the historian A. Hunter Dupree said that "for the first time since the period 1945-47 the United States is in the midst of shaping a new science policy. The old government-university partnership (has) already lost its basic rationale. . . "[46]

The academic science establishment particularly, based on a government-university partnership, was threatened from the inside by its own growth even as it was buffeted by repercussions from the war in Southeast Asia and the growing environmental crisis. Even while funds for fellowships, research, and facilities were growing during the 1960's, the increasing number of scientists wanting support lowered the per capita subsidy to each. Between 1964 and 1970 the proportion of Ph.D. academic staff in science receiving Federal support and engaged in basic research fell (for all fields) from 69 percent to 57 percent. During this same period, research funds (both Federal and other) per scientist and engineer in doctorate-granting institutions dropped from $13,138 to $11,826 (in constant 1961 dollars). To make matters worse, research support based on teaching responsibilities was undermined by the fact that by 1971 students declaring majors in physics, engineering, chemistry, and mathematics were declining. And to top off the problem, by 1971 although employment rates for scientists and engineers were better than for all workers, unemployment of scientists under 30 years of age was over 5 percent.[47] The prosperity of the sixties was proving to be less than wholly self-sustaining.

With the coming of the 1970's the once relatively prosperous and apparently stable science structure began to show vulnerability in two additional major areas: the proper measuring of effort between basic and applied research and the proper division of responsibility in science between military and civilian agencies. Behind both of these lay the changing role of the Cold War as a justification for the Federal commitment to R&D efforts. Initiatives aimed at easing of international tensions between the great powers, and a new awareness of such domestic problems as decaying cities, deteriorating public health and safety, shortages of energy and materials, and increasing pollution tested the flexibility of the science establishment. As new demands on the Federal budget competed with established R&D programs, it was inevitable that the cost-effectiveness of basic research should again be questioned.

Some attempts to answer questions about the cost/effectiveness of basic research took the form of case histories for technological innovations. The Department of Defense preliminarily released *Project Hindsight* in 1966;[48] the National Science Foundation funded *Technology in Retrospect and Critical Events in*

[45] Charles V. Kidd, *American Universities and Federal Research* (Cambridge, 1959), p.v.
[46] Editorial in *Science*, **169** (July 10, 1970).

[47] *Science Indicators—1972*, pp. 120, 121, 125, 130, 131.
[48] Chalmers W. Sherwin and Raymond S. Isenson, "Project Hindsignt," *Science*, **156** (June 23, 1967) 1571-1577. Also, Raymond S. Isenson, Office of the Director of Defense Research and Engineering, *Project Hindsight Final Report* (Washington, 1969), Available from National Technical Information Service as AD 495-905.

Science (TRACES)[49] which appeared in 1968 and *Interactions of Science and Technology in the Innovative Process: Some Case Studies*[50] which appeared in 1973. These studies attempted to document the contributions of and chronological relationships between basic research, applied research and development for selected technological innovations. Although each study highlighted the time delays between publication of basic research results and the utilization of such results, only the two NSF projects illustrated how basic research had contributed to the improved productivity, standard of living and economic status of society. However, while these case studies were underway, questions were also raised as to where basic research should be done and under whose sponsorship.

The marking out of boundaries for military research activity was tried anew in the Mansfield amendment of 1970, which sought to limit military support of basic research to those areas clearly within the military's mission.[51] Behind this effort was the belief that while basic research was a worthwhile object of Federal subsidy, military sponsorship in most cases carried a larger liability than benefit. NSF, it was hoped, would be able to pick up the funds. In practice, it proved easier to deny funds to the military than to rebudget them for a civilian agency.

As the decade of the sixties faded and the seventies began, the weaknesses of the postwar scientific system, added to some adverse results of its successes, awakened apprehension in many observers. In December 1969 a presidential Task Force on Science Policy reported that "urgent and critical funding problems do exist in many areas of science and technology today. All aspects of science policy are currently strongly influenced by the fact that, after years of rapid growth, Federal funds for the support of basic research and academic science have leveled, or, considering the effects of inflation, decreased in recent years. Intense budget pressures and very difficult priority choices exist." The report in a subsequent passage detailed some consequences of the decrease in support levels, embracing them in the phrase "this general crisis."[52]

Also in 1969 former presidential science advisor, Jerome B. Wiesner, noted that "there has been no time in the post-World War II period when the situation looked as bleak, nor were our scientists more discouraged." Wiesner called for "a recommitment to an aggressive, vital scientific program, a rededication motivated by the true need of our society, the need to be continuously inventing our future, if we are to remain a vital nation."[53]

In the context of such statements lay references, direct or implied, to the persistence of issues confronting research in the United States through much of its history. The voicing of concern was also the statement of a challenge. The history reviewed here provides hope that this challenge can be met by study and action so as to continue progress in the history yet to be written.

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[49] The Illinois Institute of Technology Research Institute, *Technology in Retrospect and Critical Events in Science*, *(TRACES)*. Prepared for the National Science Foundation, 2 vols., (1968). Available from National Technical Information Service: Vol. 1, PB 234767/AS; Vol. 2, PB 234768/AS.

[50] Battelle Columbus Laboratories, *Interactions of Science and Technology in the Innovative Process: Some Case Studies*, prepared for the National Science Foundation (C-667), March, 1973, Columbus, Ohio. Available from National Technical Information Service as PB 228-508/AS.

[51] See for example, *Science*, **169** (September 11, 1970), 1059.

[52] *Science and Technology: Tools for Progress*. The Report of the President's Task Force on Science Policy (April, 1970), pp. v, 25.

[53] Jerome B. Wiesner, "Rethinking Our Scientific Objectives," *Technology Review*, **71** (January, 1969), 15-17.

THE INQUIRY TO THE RESEARCH COMMUNITY 2

THE INQUIRY TO THE RESEARCH COMMUNITY

2

SENDING OF THE INQUIRY LETTER

As the Foreword has indicated, the purpose of this Report is to alert responsible persons in government and the public to critical issues that are currently affecting or will soon affect the conduct of research in this country. In order to determine what these issues are, the National Science Board contacted a large segment of the research community in the United States, and asked them what they see their problems to be.

Thus a letter of inquiry was sent to a selected set of persons responsible for the direction of research throughout the scientific community.[1] Each person contacted was asked to suggest "the two most critical issues/problems facing fundamental (long-term, basic) research, as you see it, in the near-term future." "What critical issues/problems will condition scientific and technological research. . . and will decrease its effectiveness unless properly addressed?" The respondents were intentionally given a great deal of freedom in the suggestions they might make. The only limitation was that the planned Report "is not as much concerned with dollar support as with circumstances in the institutional, managerial or policy environment which will influence the productivity of working scientists and engineers."

For the purposes of this inquiry, the scientific community was divided into four "sectors": university, industry, Government, and independent research institutes (IRI's). The Government sector comprises all Federal laboratories, whether they are Federal intramural laboratories or Federally Funded Research and Development Centers (FFRDC's). FFRDC's are contractor-operated R&D organizations established to meet the particular needs of a Federal agency. Examples of FFRDC's are Kitt Peak National Observatory and RAND Corporation. Independent research institutes (IRI's) are separately incorporated nonprofit organizations operating under the direction of their own controlling bodies and performing R&D in any of a wide variety of fields.

The inquiry letter was sent to the presidents and vice-presidents for research[2] at a selected set of universities, namely those that were classified by the Carnegie Commission on Higher Education as Research Universities I or Research Universities II. Research Universities I are the 52 leading universities in terms of Federal financial support and production of Ph.D.'s. Research Universities II are the 40 additional universities that are leading institutions with respect to either Federal support or production of Ph.D.'s.[3]

In addition, each university vice-president for research was asked to supply the names of the chairmen of five of his most active departments in science and engineering.[4] The

[1] The complete text of this letter is shown in Appendix B.

[2] Titles for comparable positions vary among institutions. For a fuller discussion, see Appendix A.

[3] For the exact definition, see Carnegie Commission on Higher Education, *A Classification of Institutions of Higher Education* (Berkeley, 1973), pp. 1-2. The names of these institutions are listed on pp. 9-15 of that publication and also in Appendix C of this Report.

[4] The letter employed is included in Appendix B.

inquiry letter was also sent to them. In all, 445 chairmen were contacted, from a variety of disciplines and all 92 Carnegie Research Universities. Together with the presidents and vice presidents, they represent a very considerable sampling of the research management at U.S. universities.

In the industry sector, the presidents of a group of major corporations were contacted. These corporations account for about one-half of company-funded R&D spending in the United States. The companies selected were chosen to obtain adequate coverage of those industries in which basic research plays a significant role. Several companies were selected from each of the major industries performing basic research. From industries devoting fewer resources to basic research, only one company was selected.

Letters were also sent to all 100 members of the NSF Industrial Panel on Science and Technology. These panelists were originally selected to represent the large, medium, and small firms doing research in each major industry, such as electronics, aerospace, or instruments. Typically, the top R&D official within a company is the panel member. This means that most members are vice-presidents for research or directors of research; in some cases where research is conducted by a research subsidiary, the panel member is the president of the research organization. The companies represented on the NSF Industrial Panel together account for nearly two-thirds of all industrial R&D spending.

In the Government sector, all Federal agencies with major scientific research efforts[5] were covered. Directors of selected intramural Federal laboratories and the directors of all Federally Funded Research and Development Centers (FFRDC's) were contacted. Letters were also sent to the highest ranking officials of Federal agencies dealing with science and technology. The Federal intramural laboratories were selected to represent the spectrum of research activity of the parent agency. Almost all conduct basic research; most do applied research or development as well.

Similarly, in the case of the independent research institutes, letters were sent to the presidents or directors of laboratories from 45 of the institutes that were listed as being the largest in terms of research and development expenditures in 1973. Together they accounted for 78 percent of all research and development expenditures in such institutes.[6]

The scope of this study, therefore, was quite broad. Table 2-1 shows the number of letters sent as well as the number of responses, by sector and by subgroup of respondents within each sector. The inquiry was designed so as to get a response from each sector in which science or engineering is done. At the same time, it limited the number of "issues" to two, in order to obtain a sense of priority and urgency.

By choice an open question was asked, in place of a structured questionnaire suitable for quantitative statistical analysis. This method allowed the research community to state their concerns in their own words. While it may be desirable to do a more quantitative study later, this kind of study is most suitable for an initial exploration of their opinions.

RESPONSE TO THE INQUIRY LETTER

The rate of response to the inquiry letter was gratifyingly high. This can be seen from Table 2-1, which shows the number of letters sent for each sector, the number of responses received,

[5] Based on *Investigative Report on "Utilization of Federal Laboratories"*, which is Part 7 of *Agriculture-Environmental and Consumer Protection Appropriations for 1975 Hearings*, U.S. House of Representatives, Committee on Appropriations, Subcommittee on Agriculture-Environmental and Consumer Protection, 93rd Congress, 2d Session, 1974.

[6] This figure was obtained from the authors of *R&D Activities of Independent Nonprofit Institutions, 1973*; NSF 75-308. As the discussion below indicates, not all of these 45 institutes were still in existence at the time of the letter inquiry.

and the percentage rate of response.[7] The industry sector had the highest rate, 81 percent. The return from university presidents and vice-presidents for research was also quite high, at 82 percent and 78 percent, respectively. The response from department chairmen was smaller, perhaps because they were contacted at an awkward time in their schedules. While the other administrators were contacted in May and June, the letters to chairmen did not go out until late summer. FFRDC's (59 percent) and independent research institutes (53 percent) showed the lowest returns. Five of the independent research institutes taken from the 1973 listing had gone out of business by the time of the letter inquiry. Hence Table 2-1 shows only 40 institutes as having been contacted.

The high overall rate of response indicates an intensity of concern within the research system about its immediate future, and the quality of these responses is evidence that a great deal of serious thought went into them. The National Science Board greatly appreciates the valuable contributions that the respondents have made to this Report.

Table 2-1. Responses to the NSB Inquiry Letter

		Letters Sent	Responses Received	Percent
University				
Presidents	Research Universities I	52	41	79
	Research Universities II	40	34	85
	Total	92	75	82
Vice Presidents for Research	Research Universities I	52	40	77
	Research Universities II	40	32	80
	Total	92	72	78
Department Chairmen	Research Universities I	250	172	69
	Research Universities II	195	122	63
	Total	445	294	66
Total for Universities		629	441	70
Industry				
NSF Industrial Panel		100	78	78
Presidents of Corporations		51	45	88
Total for Industry		151	123	81
Government				
Directors of Federally Funded Research and Development Centers (FFRDC's)		37	22	59
Directors of Intramural Laboratories		36	25	69
Agency Officials for Science and Technology		8	8	100
Total for Government		81	55	68
Independent Research Institutes				
Presidents or Directors of Institutes		40	21	53
Overall Total		901	640	71

[7] Appendix C lists the names of the respondents and their institutions, according to sector.

ANALYSIS OF THE RESPONSE LETTERS

When the response letters were received, they were subjected to a content analysis. The purpose of this analysis was to develop the most suitable set of categories under which to classify the problems and suggestions contained in the letters. The original inquiry letter had not contained any such categories, since its intent was to give the respondents as much freedom as possible in their replies.

Table 2-2. Issues Most Often Mentioned from the University Sector

There is pressure for applied research in preference to basic or pure research; projects are overly "targeted" or their subjects too minutely defined.
There is need for more continuity and stability in government funding of research; research grants should be longer.
Hiring and research support problems are experienced by younger faculty; departments cannot hire because of tenure; older faculty do not leave.
The continued supply of manpower to do research must be insured.
More coordination of research at the national level, more consistent policy, and more planning are needed.
More support is needed for graduate studies.
More money in general is needed for research; there should be more basic research.
The public has a negative attitude toward science and technology.
Government (State, local, or Federal) or one of its branches or agencies has a negative attitude toward science and technology.
Funds are needed for research equipment, instrumentation, and maintenance.
Increased teaching loads take time away from research.
More support for university research should be supplied at the institutional level.
A program of education or communication is needed to convince the public and government of the value of research.
There are excessive demands for accountability in the use of funds provided by government.

Table 2-3. Issues Most Often Mentioned from the Industry Sector

Government regulations and controls (unreasonable, not thought out, no cost/benefit/risk analysis).
Absence of national science and technology policy, priorities or goals.
Near-term relevance is only research objective (due to government regulations or decentralization of research to profit centers).
General economic conditions, particularly inflation in salaries and laboratory costs, lead to decreases in fundamental research in industry.
Low public confidence in and/or poor image of science, technology, research or scientists.
Lack of availability of money, low profitability or obstacles to capital formation lead to decreases in fundamental research in industry.
Concern over general decrease in fundamental and other research in industry.
Deteriorating patent protection or patent policy is a disincentive to industrial research and innovation.
Too few/too many scientific and technical personnel—no match with need—lack of national policy on scientific and technical personnel.
Competing R&D functions (e.g., applied research or development in response to government regulations) decrease fundamental research in industry.
Concern about quality of new people—best are not entering science and engineering or, if they do, are kept for university.

The letters were first divided according to sector. For each sector, an initial set of letters was read, and a list was made of the problems and suggestions that they discussed. This list was reduced to a smaller list that combined statements of issues that were very similar, and this became the first tentative list of categories. The list was revised as more letters were read until categories were reached that would cover almost all of the responses. A count was kept of the number of responses that fell under each category. Further details of the analysis can be found in Appendix A. Some members of the National Science Board verified the list of categories by their own independent reading of the letters.

The categories that were developed from the letters by the above method are the concerns and needs of the Nation's scientific enterprise as these are perceived within each sector. Tables 2-2 through 2-5 list the issues mentioned most often from each sector, roughly in the order of their frequency. A complete list, which includes the less frequent issues, is given in Appendix D.

RESULTS OF THE ANALYSIS

If one examines the four tables of issues from the four research sectors (Tables 2-2 to 2-5), it is striking that all the sectors expressed such similar concerns. The preliminary analysis of the response letters divided the Nation's research effort into separate sectors, but it can now be seen that the commonality of interests among these sectors is much more significant than their differences. This is one of the most important results of the present Report.

The similarity of interests can be exhibited most easily by rearranging all the issues listed in Tables 2-2 to 2-5 so that similar issues from the different sectors appear together. This leads to a new set of tables, each of which combines issues from all sectors under a common heading.

Table 2-4. Issues Most Often Mentioned from the Government Sector

Need for coordinated research policy at the national level involving long-range planning, commitments and priorities.
Increased emphasis on short-term research and neglect of basic research.
Overmanagement as evidenced by too many restrictions, especially on longer-term research.
Need for increased or stable funding.
Desire for improved personnel management (e.g., personnel changes, salary scales, staff levels, etc.).
Need to maintain research staff vitality with more positions for young scientists and continuing education for older ones.
Meeting public demand for justification of basic research programs with respect to mission.
Lack of Congressional or Executive support and understanding of basic research.

Table 2-5. Issues Most Often Mentioned from Independent Research Institutes

Need for long-term continuity in funding.
Lack of coherent national science policy especially toward IRI's.
Need for adequate justification of research.
Manpower needs—particularly in IRI's—as problems associated with multi-disciplinary efforts.
Federal pressure toward over-direction of research with emphasis on short-term or applied research.
Need for research funds including construction funds.

The following four headings were selected as the most suitable ones under which to group the issues:

- Dependability in Funding for Research
- Vitality of the Research System
- Freedom in the Research System
- Confidence in Science and Technology

In Tables 2-6 to 2-9, therefore, the issues from the four preceding tables are rearranged under these new headings. Within a table, the issues under each sector that were mentioned most often are listed first. The headings state the broad issue areas that include the particular issues reported by the respondents.

These new tables provide the basic structure for the remaining chapters of this Report. Each of the following four chapters will be based on one table and will discuss the issues listed in that table, thereby covering all of the research sectors. The discussions will consist essentially of quotations taken from the response letters. The interconnections between the issues will be pointed out, as well as the similarity of views among the sectors. In this way, it is hoped that a clear picture will emerge of the deep concerns that the research community has expressed about its prospects at this point in its history.

Table 2-6. Important Issues Pertaining to Dependability in Funding for Research

University
There is need for more continuity and stability in government funding of research; research grants should be longer.
More coordination of research at the national level, more consistent policy, and more planning are needed.
More money in general is needed for research; there should be more basic research.
Funds are needed for research equipment, instrumentation, and maintenance.
More support for university research should be supplied at the institutional level.
Industry
Absence of national science and technology policy, priorities or goals.
General economic conditions, particularly inflation in salaries and laboratory costs, lead to decreases in fundamental research in industry.
Lack of availability of money, low profitability or obstacles to capital formation lead to decreases in fundamental research in industry.
Concern over general decrease in fundamental and other research in industry.
Government Laboratories & FFRDC's
Need for coordinated research policy at the national level involving long-range planning, commitments and priorities.
Need for increased or stable funding.
Independent Research Institutes
Need for long-term continuity in funding.
Lack of coherent national science policy especially toward IRI's.
Need for research funds including construction funds.

Table 2-7. Important Issues Pertaining to the Vitality of the Research System

University
Hiring and research support problems are experienced by younger faculty; departments cannot hire because of tenure; older faculty do not leave.
The continued supply of manpower to do research must be insured.
More support is needed for graduate studies.
Increased teaching loads take time away from research.

Industry
Concern about quality of new people—best are not entering science and engineering or, if they do, are kept for university.
Too few/too many scientific and technical personnel—no match with need—lack of national policy on scientific and technical personnel.

Government Laboratories & FFRDC's
Desire for improved personnel management (e.g., personnel changes, salary scales, staff levels, etc.).
Need to maintain research staff vitality with more positions for young scientists and continuing education for older ones.

Independent Research Institutes
Manpower needs—particularly in IRI's—as problems associated with multi-disciplinary efforts.

Table 2-8. Important Issues Pertaining to Freedom in the Research System

University
There is pressure for applied research in preference to basic or pure research; projects are overly "targeted" or their subjects too minutely defined.
There are excessive demands for accountability in the use of funds provided by government.

Industry
Government regulations and controls (unreasonable, not thought out, no cost/benefit/risk analysis).
Near-term relevance is only research objective (due to government regulations or decentralization of research to profit centers).
Deteriorating patent protection or patent policy is a disincentive to industrial research and innovation.
Competing R&D functions (e.g., applied research or development in response to government regulations) decrease fundamental research in industry.

Government Laboratories & FFRDC's
Increased emphasis on short-term research and neglect of basic research.
Overmanagement as evidenced by too many restrictions especially on longer-term research.

Independent Research Institutes
Federal pressure toward over-direction of research with emphasis on short-term or applied research.

Table 2-9. Important Issues Pertaining to Confidence in Science and Technology

University

The public has a negative attitude toward science and technology.

Government (State, local, or Federal) or one of its branches or agencies has a negative attitude toward science and technology.

A program of education or communication is needed to convince the public and government of the value of research.

Industry

Low public confidence in and/or poor image of science, technology, research or scientists.

Government Laboratories & FFRDC's

Meeting public demand for justification of basic research programs with respect to mission.

Lack of Congressional or Executive support and understanding of basic research.

Independent Research Institutes

Need for adequate justification of research.

DEPENDABILITY IN FUNDING FOR RESEARCH

3

DEPENDABILITY IN FUNDING FOR RESEARCH 3

The issues constituting "Dependability in Funding for Research" display two broad aspects. One pertains to funding for research projects, with special emphasis on continuity and stability. The other involves planning and policymaking in the overall management of research funding at the institutional level and at the national level. A principal goal of this planning and policymaking is assured continuity and stability in funding for research.

Respondents noted that research is characteristically a slow and methodical process by which new knowledge is sought through systematic investigations. The outcome of these investigations, they emphasized, cannot be predicted; the results of following a lead may turn out to be negative or may indicate fruitful new paths for further research. So, respondents argued, the research scientist ideally should be able to count on stability and continuity in his research support wherever it may lead. However, the present collection of letters indicates that certain conditions make such reliable support difficult, and in some cases, impossible. The destabilizing conditions, factors or situations mentioned in the letters differ by research sector and by source of supporting funds. Nonetheless, throughout the sectors of research, respondents identified uncertainty in funding as a source of problems. In several cases, respondents explicitly pointed out that the desire for dependable funding is not just another way of asking for more money. They went on to say that the continuity is more important than the level of support.

The leading issues pertaining to dependability of funding for research are presented in Table 2-6 of Chapter 2 and are discussed below.

Industrial responses generally noted decreases in research, especially more basic research, and frequently related these decreases to changes in funding due to prevailing economic conditions such as inflation, low profits, and decreased availability of capital. The industrial respondents also reported an absence of policy, priorities or goals for science and technology at the national level.

Within the university sector, the issue cited most often that has to do with dependability in funding for research is the need for continuity and stability in Government support. Multiyear funding is a solution frequently proposed to meet this need. University respondents also frequently suggested two other means for dealing with the problem of continuity and stability: long-term planning for research funding by the Federal Government, and providing support directly to the university for subsequent allocation by university officials to campus research activities (a so-called institutional form of support). Another issue frequently cited is the need for funds for research equipment, instrumentation and maintenance. A significant minority in the university sector expressed concern about the adequacy of dollar levels of funding—a subject outside the preferred areas of attention designated in the letter of inquiry.

For the independent research institutes, the leading concerns were the need for long-term continuity in funding for research, the absence of a coherent national science policy especially with regard to IRI's, and their current need for more money.

Respondents from Federal intramural laboratories and the Federally Funded Research and Development Centers (FFRDC's) expressed a need for long-range planning and focussed on the commitments and priorities implied by a workable, coordinated national research policy.

In the following pages, individual quotations document the respondents' concerns about dependability of funding for research and the possible role of national planning and policy in assuring such dependability.

INDUSTRY

Ruben F. Mettler, President, TRW, identified factors which he felt have had and will continue to have a strong adverse impact on fundamental research in industrial laboratories, and which also have negative effects on fundamental research in university and Government laboratories. Some relevant sections of his letter are quoted here:

> To place my views on this subject in context, I should say that I regard fundamental research as a long-term investment for a corporation. Hence, along with other long-term investment, fundamental research should be relatively well insulated from minor or short-term fluctuations in business results. However, along with other long-term investment, fundamental research is not insulated from more basic trends affecting business results, and it is two of these basic trends which I wish to identify as endangering the effectiveness of fundamental research.

Dr. Mettler first identified "inflation" and noted:

> The cumulative effect of inflation has, of course, a strong bearing on the amount of capital American companies need to invest in order to maintain investment levels comparable with historical levels. Even if current inflation levels now drop (perhaps only temporarily) it will take years of significantly higher corporate investment levels to compensate for the effects of inflation.

He also mentioned declining capital resources and continued:

> Just when inflationary forces require higher levels of corporate investment, the capital resources of American corporations are declining. The steady decline in corporate profitability, and a continuing long-term bias in national policy over the past several decades resulting in increased personal consumption in preference to capital formation, have squeezed the basic capital resources—as measured by retained earnings—of American corporations to such an extent that we now see a declining trend in long-term investment in real (non-inflated) terms. This decline in long-term investment generally has included declining investment in fundamental research.

James Hillier, Executive Vice President, Research and Engineering, RCA, presented in a way typical of many industrial responses the capital formation problem as it relates to research and innovation in the current economic climate:

> There is a well-known and well-established relationship stating that one dollar spent on *successful* basic and exploratory research requires ten dollars worth of development to make it *ready* for introduction and utilization in the economy and, further, that an additional one hundred dollars of investment in plant, training, marketing and promotion is required for its introduction and its support to the point of self-sustained viability. It is also known that for significant innovations the entire process usually takes about ten years to go from the successful basic and exploratory research to self-sustained viability. Cash investment is required throughout this period and even considerably beyond if the rate of growth of the business is high. Finally, recognizing that only a fraction of the basic and exploratory research projects in industry are successful in the sense of being suitable for proceeding into a business venture, it must be appreciated that the total process can be *continually* supported only by companies that are larger than some minimum threshold in size

(currently around $250 million in sales). Implicit in this process is the assumption that investment dollars will be easily and inexpensively available throughout the entire period of development. Any such project is a long sequence of decisions, each of which has economic significance to the company for some time in the future. Yet these decisions must be made within the constraints of the *current* economic environment and its projection into the future.

The present economic and more importantly the present political environment forces most prudent businessmen to the conclusion that the assumption of easily available capital is no longer valid, particularly insofar as it applies to the long-range future. The result is a trend, already apparent in industrial research, toward short-term projects and a definite de-emphasis in the basic and exploratory research.

Concerning the need for assurance of continuity, D. Furlong, Vice President of Bechtel Corporation, San Francisco, wrote:

Some mechanism is needed to ensure reasonable levels of continuity in programs of fundamental research. Steady application of talent is needed over the long term to produce useful results, and it is difficult to see how such results can be obtained from crash programs or cyclical funding.

Donald W. Collier, Vice President-Technology, Borg-Warner Corporation, described some effects of the economic environment upon research:

The economic recession, coupled with the realization that resources (capital, energy, non-replaceable materials, etc.) are indeed limited, has caused a decided and what may be relatively long term shift in research policy from an outward-looking exploratory one to an inward-looking short term one. Top priority is being given to increasing efficiency, conserving resources and improving effectiveness of our operations. There is a decided backing away from research which is outward looking, expansive, and high risk. This has resulted in research being much more closely tied to current operations, and in some cases the dismemberment and dissipation of longer range research facilities and staffs.

Albert E. Cookson, Senior Vice President and General Technical Director, ITT, wrote that despite the request of the NSB inquiry letter to restrict concerns over "dollar support", he felt that an adequate and consistent level of funding for R&D remains a matter of paramount importance:

In the industrial environment, with a reasonable return on investment being impacted by inflation and interest costs, it is becoming an increasingly more difficult task for management to maintain an adequate level of R&D. Considering the urgent short run needs for cost reduction and improvement of products required to maintain competitiveness and enhance the usefulness of present product lines, the resources that can be allocated to longer range R&D are being squeezed to the point where it is very difficult for industry to maintain a viable level of effort.

Many industrial respondents also shared the judgment of N. B. Hannay, Vice President, Research and Patents, Bell Laboratories, who feared the demise of basic research efforts in contemporary American industry:

. . . I would say that the single most critical issue with respect to long-term research in industry is that it is not being done, for the most part. A few companies in a few industries support it, but the bulk of industry has either given it up or never did it. I believe that it is critically important for the country to encourage industry in the support of long-term research.

. . . there are a number of factors that have contributed to this situation. Regulation, antitrust attitudes, the cost of money, inflation, the lack of faith in many segments of industry that the benefits of long-term research can be captured by its sponsor, and over-emphasis on short-term financial results are among the important causes. If the Federal government were to adopt as public policy a positive attitude toward the encouragement of industrial research, I believe we could reverse the current trend away from long-term research.

Other industrial respondents supplied their own assessments on determinants of the present state of research in industry. Thomas R. Miller, Vice President of Union Carbide Corporation, saw a conditioned business response to industrial profit reductions which is a critical problem in that:

> Research and development is a highly visible overhead expenditure and is usually high on the list for reductions when profits are too low, as they are for capital formation purposes. Generally, basic research is cut back the most.
>
> A possible remedy might take the form of some kind of preferential tax treatment for R&D.

In describing how research organization impacts on the conduct of research, I. H. Stockel, Director, Research and Development, St. Regis Paper Company, wrote:

> Beginning in the late 1960's, industrial research in this country began undergoing a change of major proportions which is virtually complete today. Prior to the change, industrial research laboratories were set apart from the rest of their company's organizations and were less affected by changing economic conditions. Industrial laboratories of today have become fully integrated members of the corporate team which, for the most part, is a very healthy condition which was long overdue. One important disadvantage is that our budgets and priorities have become more affected by the changing economic conditions of the country. For the most part, this has had a beneficial effect on the careful selection of development and other application projects, and on the profitable utilization of industrial research. However, it has had an adverse effect on longer-range programs and, in turn, on the support and attention given to basic research, whether it is conducted within the industrial research laboratory, on contract to outside laboratories, or in the form of various kinds of support and encouragement to schools and other institutions.

Frequently among industrial responses, a discussion on patterns for research support raised questions about planning and policy. Concern over policy goals and priorities at the national level is typified in the short comments below:

> One issue certainly is the *lack of clearly defined national policies* in important areas.
>
> N. V. HAKALA, *President*
> Exxon Research and Engineering Company

And, more explicitly, Daniel E. Noble, Chairman, Science Advisory Board, Motorola, Inc., wrote:

> We cannot determine where to place the emphasis on research and development unless we decide where we wish to go and how we expect to get there. The greatest need in our society today is for the establishment of goals and priorities, but the goals and priorities must be determined by a realistic understanding of all of the forces of our environment which will influence the feasibility and practicability of the selection. It all relates to the hard-headed decision: since we can't do everything, we should damn well be sharp about the importance of the projects we select for activation. We cannot possibly be sharp about the selection of the projects unless we have an overview of where we want to go and how we expect to get there. So this all comes back to the basic need for an overall systems dynamics model which can guide us in our selection of the most important areas for research and development emphasis.

John O. Logan, President and Chairman of the Board, Universal Oil Products Company, Des Plaines, Ill., observed:

> The one area which bothers us most relates to the government-industry interface. On the one hand, legislated scientific and technical goals executed under governmental control tend to prescribe results, thereby defeating some of the fundamental objectivity required in basic research. On the other side of the same coin, the lack of action on the part of the government to commit long-range funds, or to avoid any statement of objectives, leaves basic research wallowing in a sea of uncertainty.

Along these same lines, David H. Bradford, Jr., President, and now member of the Board of Directors of Allied Chemical, noted:

> Hopefully we will suceed in developing a closer integration of the goals of industry and national social and economic goals through a more clearly

defined set of national policies. If so, a stimulus to more fundamental research in industry can be achieved.

Respondents felt that important functions of a national R&D policy would be the identification of goals and the selection of the best means for achieving those goals; initial steps would involve recognizing what various parts of the research system do best and then arranging for these parts to work together.

Thus, Robert M. Adams, Vice President, Research and Development, Minnesota Mining and Manufacturing Company, believed a national policymaking effort could help define the best mechanisms for university, government, and industry interaction:

> The United States still seems to be groping for the proper role of these three "institutions" in the nation's research and development activity. University research grew dramatically in the 50's and 60's with the support of Federal funds. This support has been diminished in the 70's, and in many cases universities have turned to industry to replace at least some of the lost Government support. The equilibrium between these three forces has been disturbed and has not yet really settled out. Even within the universities there is much disagreement on priorities, allocations, and directions. Until the roles of government, industry, and universities are more clearly defined, it is probable that fundamental research will stumble.

In a similar vein, W. Dale Compton, Vice President, Scientific Research, Ford Motor Company, noted a need to develop, on a national scale, mechanisms that will enhance the interactions between industrial research teams and university research groups:

> Basically, there exist now only *ad hoc* mechanisms that are, at best, tenuous. Both groups would benefit from a closer working relationship. I think this would also help stabilize the long-term research efforts of the various groups, both in the universities and in the industrial laboratories.

UNIVERSITY

Although the perspective of industry and of the universities may differ somewhat, the problems they perceive are similar as can be seen from the letter of Sidney G. Roth, Vice Chancellor for Federal Relations at New York University. As quoted here, he sets out the key elements of Dependability in Funding for Research as they are seen from the university:

> Academic institutions are asked to undertake as well as suggest research programs which are basic to issues of national need. Clearly, Federal priorities are important and dollar resources must be authorized and appropriated to implement national policies with respect to such major problems. But, as we look back over the past two decades, we can document those efforts that peaked all too quickly in almost each of the major areas. The OMB, Congress, or other Federal entity seems to get tired of a given program and either pushes on to a new priority because of political considerations or modifies its previous effort by eliminating it or changing the rules drastically.
>
> On the other hand, academia is urged to mobilize its resources to assist in these needed developments. If an institution thinks it can make a contribution, it will do so hoping thereby to meet a societal obligation and at the same time participate in the development of new programs of promise. And, academic institutions generally invest a considerable sum of their own funds when undertaking major ventures of interest to the Federal establishment. When Federal support changes abruptly or with very short notice, such institutions can be left in an embarrassing position.
>
> Further, the time scale for academia generally is longer than a year or two or even three: people have to be hired; students acquired; facilities altered or constructed. If an institution beefs up a given department, faculty, or program by adding highly qualified staff, immediately it must think of the future. Will the institution be able to afford the number of people on its roster after the initial funding is over? Will it be in a position to fulfill its promise to students in process by continuing

stipends and course offerings? Will the facilities so acquired be useful or become a burden in a few years? etc., etc.

Faculty appointments represent an investment for long periods, probably 10 to 20 years or more. Students, graduate and professional, have careers ahead which demand three, four or more years of preparation. These are the time scales of academia. Federal agencies, on the other hand, drop programs quickly when immediate manpower needs shift or new ventures appear that seem to be politically more saleable.

How, then, do we meet our common goals via our separate sets of rules? Important programs are now on stream, RANN among others. How do we avoid the pitfalls that befell these other attempts?

In summary, one may provide a litany of issues which develop from the different planning assumptions in our two sectors; different perceptions of what may be required to meet common goals; different time scales inherent in each sector's life style. These are knotty issues but they have to be solved before a serious problem materializes on the higher education front. Some first-rank institutions will probably collapse. Is that the price the nation must pay before the system is corrected?

These comments and those that follow illustrate the reasons why questions related to continuity, stability, and length of funding ranked second among each of the three groups of respondents from the universities: presidents, vice-presidents, and chairmen.

Herbert W. Schooling, Chancellor, University of Missouri-Columbia, wrote about continuity and stability problems in the past and how they might be remedied:

. . . I believe we have learned that funding procedures which have been erratic and sporadic have not given the universities the opportunity to create and maintain always the kind of climate in which higher education, as a community of scholars seeking truth, could best serve as partners with the government in advancing knowledge. Brief periods of funding have tended to make institutions vie intensely for grants on a thin and broad basis which did not allow for the development of a concentrated team of researchers, appropriate machinery, and graduate students who are necessary for ongoing work of high quality, excepting the medical sciences. Designations of certain communities of scholars interested in and capable of significant research in certain areas which are of critical interest to the nation's needs would provide a way to establish and maintain relationships which may continue for periods of time of a decade or so without interruption under normal circumstances.

Also from within the university community, Jerome B. Wiesner, President of M.I.T., expressed the problem of continuity and stability as follows:

The fluctuations in Federal funding of basic research which we have seen recently are extremely damaging. The upswing to 1968 and the precipitate decrease since then have led to serious imbalances between fields; to an apparent lack of opportunity in some fields which drives good young people away, only to present us with "shortages" in the future; to the destruction of many research teams carefully assembled over many years of effort; to the underutilization of important facilities and in some cases to their premature demise. A long-range science policy which gives some assurance of continuity is badly needed.

In the view of John R. Silber, President of Boston University:

Research programs which provide only short-term support, or faddish changes in the kinds of programs which are being encouraged, will be extremely detrimental to scientific research, to institutions, and to individuals. Slightly fewer grants of longer duration for truly significant projects would provide a stability in research which counters the instability of the enrollment declines and inflationary forces.

The importance of dependability in funding for research as seen at the department chairman level is expressed by T. T. Sandel of the Department of Psychology, Washington University, St. Louis:

For the last three years, we have proceeded from alarum to alarum, being told that this or that area of research would be phased out, beefed up, or what have you. An incredible amount of time has been spent by all our principal investigators either rebudgeting, writing new proposals, changing lines of thrust of research, etc. In general, the effort has had some aspects of a dumb show because the actual cutbacks have seldom taken, in detailed form, the directions which were originally predicted. In a word, our ability to plan on any reasonable temporal basis is, to all effects, nonexistent. Clearly, a major contribution to the health of our scientific efforts would be to develop a mechanism whereby the capriciousness of Congressional funding (with its one-year structure) and the political aims of a given administration would be minimized.

The outlines of the solution to this problem are blurred, at best. I can't help feeling, however, that the solution lies in some kind of institutional funding scheme . . .

Continuity and stability of funding was the second most frequently mentioned issue among each of the three levels of university respondents. Among engineering chairmen it was, in fact, the first. One remedy often suggested for this problem is an increase in national research planning. Although this solution was not frequently mentioned among departmental chairmen, it ranked third among all presidents and vice presidents combined. It was especially high in Carnegie Research Universities I, but quite low in Research Universities II.

F. N. Andrews, Vice President for Research and Dean of the Graduate School at Purdue University, stated the need for policy and planning as he sees it:

We believe that the Federal Government should develop a clear and specific long-range plan for the support of basic research and for the appropriate applications of research through the development process. It is essential that a new and effective mechanism for science planning, with direct access to the President, be established. The nation suffers because there is no publicly announced, long-range policy—a plan that would include specific proposals for the next decade and which would be sufficiently broad in its scope to plan for the remainder of this century.

In this connection a scientific advisory apparatus in the White House was frequently mentioned. For example, Charles G. Overberger, Vice President for Research at the University of Michigan, gave the opinion that "an office and an agency are needed which can ensure that our national resources for research are adequate and that these are most properly placed."

Another frequently mentioned solution for instability in the funding of individual grants or contracts at the university was direct support to the institution itself. This suggestion ranked fifth among all university vice presidents for research and sixth among all university presidents, but was rarely mentioned by department chairmen. Further, although the Research University II presidents and vice presidents combined ranked the issue of institutional support first, the presidents and vice presidents combined at Research Universities I did not place this issue in their top eight. This is one of the differences between responses from Research Universities I and II.

The need for institutional funding is argued by John L. Margrave, Dean of Advanced Studies and Research at Rice University:

There is continuing need for institutional grants of the type which have historically been made by both the NSF and the NIH, in which an institute receives a percentage of the total grant amount directly in the form of a lump-sum payment to the office of the president or chief administrative officer. This uncommitted money provides the administrative leader of a university an extremely useful capacity to commit seed money for the development of new ideas at early stages of a research program, to supply supplementary funding to stabilize a faculty member's research program, and to handle other contingencies for faculty or research students. In particular, the "new ideas" which often are speculative and may not always stand the strict review of a large panel can be given a quick review at the faculty member level and then, after that evaluation, used as the basis for seeking larger amounts of support from external sources. Support of a new imaginative young faculty member at this stage of his career can be extremely important and, of course, very productive in the practical sense.

A. R. Chamberlain, President of Colorado State University, considered institutional support the answer to what he sees as the fragmentation of university funding and of university efforts.

The universities need financial support on an *institutional* basis, supplementing the project approach now so dominant, that permits a university administration to have a leadership role in resource allocation for program priorities that are institutionally determined by the joint involvement of campus administration and faculty. To do less will leave research and graduate education to be pressed by project grants into a further hodge-podge of isolated projects with no coherent institutional programmatic theme. Such a consequence leads to inefficient use of funds . . .

Randal M. Robertson, Dean, Research Division, Virginia Polytechnic Institute, shared these sentiments and applied them to Research Universities II:

The need for continuity could be met by providing more support through a formula system such as the Hatch Act provides for agricultural research. Such support should give funds to an institution for a continuously renegotiated set of projects. The competitive proposal system, with its all or nothing feature, destroys continuity at the departmental level at institutions where the resulting statistical fluctuations are significant in comparison to the research activity level. This is especially true at the "second fifty" institutions. Some combination of continuing formula support and competitive grants and contracts would seem the best combination for the basic research enterprise. Formula funds should be provided directly from a Federal agency to a responsible institution, not through a state agency or through revenue sharing.

INDEPENDENT RESEARCH INSTITUTES

Among the presidents and the directors of independent research institutes, the need for long-term continuity in funding ranked first. The need for a coherent national science policy for IRI's was second, and the need for additional research funding ranked fourth. These three issues are the major components of dependability in funding for research as seen at independent research institutes.

Bowen C. Dees, President, The Franklin Institute, provides a background for appreciating the issues involving dependability in funding for research at the independent research institutes. After pointing out that the IRI's are quite varied as to age, size, field of interest, type of facilities, and equipment used, Dr. Dees notes:

Unlike the other principal organizational units concerned with R&D (the universities, industrial research units and government laboratories) the typical independent research institute has little or no endowment or the equivalent: that is, it rarely has a "parent company" to look to for base support, or to take over full support of at least some of its senior research personnel (as is possible in most universities) when grants or contracts expire. Virtually all of the major IRIs rely almost totally on the grants or contracts they receive to maintain their fiscal integrity; as a consequence, one finds that:

1. Substantial fluctuations in support can be disastrous to major programs.
2. Untoward amounts of time, energy and effort (and hence precious dollars) must be expended in the attempt to bring in new grant or contract support.
3. In those cases where contracts may appropriately carry a "fee", the fee proceeds become extremely important as a way of maintaining a quality program (a fact which is not only not appreciated but is in effect denied by many agencies and contracting officers who insist on keeping fee percentages far below realistic levels) . . .

Narrowing in on the long-term continuity of funding, George K. Hirst, President and Director, The Public Health Research Institute of the City of New York, Inc., wrote:

> . . .The second problem, assuming that our municipal support continues, I would say is clearly the large fluctuations in Federal support of research, and I think especially basic research. It has become impossible to predict from year to year what the level of Federal support might be. Not only does the rating at which funding is cut off vary, but on top of a restrictive rate we are faced with severe cuts in proposed budgets. The fellowship program has been turned on and off. General Research Support has been threatened with extinction every year. The one to two hundred thousand per year which we get under this program cannot be wisely spent for any long-range project because we don't know if it will continue.
>
> I think that research people are very adaptable and will make adjustments to a wide range of support levels but if the fluctuations could be cut out it would be a very productive thing. Is there any way that Congress could be persuaded to assure some level of Federal support for say 5 years ahead on some sort of evergreen basis?

This topic is covered in a slightly different way by Norman M. Bradburn, President, National Opinion Research Center, University of Chicago:

> Our primary problem now is the same as it has been over the past decade and promises to be over the next decade—namely continuity of funding. For research institutes such as ours that lack endowments or other long-term support, it is extremely difficult to recruit and hold the high quality scientific and technical manpower necessary to do sustained basic research. This is a general and well-known problem that has been commented upon by every major report and committee that has looked into the problems of funding basic research. Nonetheless the research funding agencies have consistently failed to heed the warnings and, if anything, have moved in the opposite direction. Some years ago we were able to get five-year project grants from NSF; now we cannot get more than a two-year grant. There has been talk about general support grants, and in the past something very near to it has been possible in isolated cases. Now the move is toward more narrowly defined research projects with shorter time horizons and with pressure toward applied pay-off. The fact that the problem has been with us for a long time and that things have gotten worse rather than better does not detract from the fundamental truth of the proposition that short-term, project oriented funding is detrimental to the development of research excellence in an independent institute (or anywhere else for that matter).

Regarding national science policy, Charles R. Wayne, Executive Vice President and General Manager, SURC (Syracuse University Research Corporation), stated that it is no longer possible for this Nation to fund adequately every problem area which it feels is in need of solution:

> We should set national priorities and define critical research needs: energy, conservation, poverty, old age, sickness, military superiority, etc. . . . I am very pessimistic that we will. The allocation of funds will continue to be a function of factors which are themselves not necessarily part of a logical long-range plan directed at our overall best interests. Because of this, large sums of money will be spent, although often not enough to produce the desired results, in areas which are fashions or fads led by charismatic leaders. So while Rome burns, we, scientists, will continue to fiddle.

FEDERAL INTRAMURAL LABORATORIES AND FFRDC's

The ideas of dependability, predictability, and stability in the funding of research emerged over and over in the responses from the intramural Federal laboratories and the Federally Funded Research and Development Centers (FFRDC's). These items were often joined to the first-ranked issue among this group of respondents—the need for a coordinated research policy at the national level.

Regarding this first-ranked issue, Betsy Ancker-Johnson, Assistant Secretary for Science and Technology, Department of Commerce, concluded:

> The most fundamental problem, as I see it, is the lack of a national science policy. To quote Dr. Hornig when he was Director of the Office of Science and Technology and Chairman of the U.S. Delegation to OECD on science policy, "There is no such thing in the United States as a Science Policy which can be isolated from other policies of the Government." (OECD *Reviews of National Science Policy: United States,* Paris, 1968, p. 451). This policy deficiency has resulted in a fragmented approach to science and technology which has led to a less effective use of science resources than might prevail with a comprehensive and coherent national science policy. A policy is "a standing answer to recurring problems"—we need better answers.

In several letters, respondents pointed out that research—especially basic research—is not something in which progress is measured in days, weeks, or even months. On the other hand, they noted, political issues used to generate support for research are often of much shorter duration than research projects. To work productively, the scientist needs the ability to begin a lengthy experiment or series of experiments with a reasonable assurance that he will not be forced to reorient it in midstream or terminate it prematurely because of funding cuts. As John W. Firor of the National Center for Atmospheric Research wrote:

> The timing mismatch can lead a scientist to undertake a project and then discover his support dwindling or cut off before he is half-way through.

Respondents argued that a scientist also needs the freedom and flexibility to be able to follow up unexpected findings which may crop up in the course of his work. In the absence of relatively secure funding, he may find himself forced to choose the safer path of working primarily on short-term experiments—which may be of less scientific interest and value—in order to avoid the catastrophic eventuality of working several years on a project and then having nothing to show for it because he was unable to complete it. Thus, instabilities in research support may limit the productivity of research beyond the constraints placed upon it by the absolute level of funding.

In a comment typical of those from the intramural Federal laboratories, W. R. Lucas, Director of NASA's Marshall Space Flight Center, put it this way:

> The practice of funding programs on an annual basis creates an instability that operates strongly to the detriment of a healthy, sustained basic research program. It must surely be recognized that such research must fare poorly in an environment characterized by uncertain support. . . .
>
> In supporting such research, short period or annual funding simply does not provide the degree of flexibility or freedom required to permit an adequate development of the potential inherent in a given field of inquiry. Funding currently applied through the close management process visualizes a straight, clear-cut path leading to a precise destination. Clearly the concept is at odds with reality. For full development, a researcher should be afforded the freedom of movement that is required in any process that explores the unknown. The restrictive practice of holding resource allocations within tight limits frustrates this freedom and, I venture to say, may well be responsible for cutting short promising activity that could otherwise have led to important results. A multiyear funding policy, in moderation, of course, would serve to release the scientist from the strictures currently prevalent in close-in funding practice with its attendant uncertainties.

In comparison with the individual research investigator, it was observed, the problem of dependability in funding for research is compounded for institutions, especially those big science institutions which maintain large-scale expensive facilities. Respondents pointed out in their letters that many such big science institutions have been established in this country on the FFRDC model, and that for these institutions to operate in a rational and effective manner, they require some assurance of predictable funding over a period of years so that they may amortize the vast investments they must make in facilities and equipment. Respondents also noted that there is no "market" on which big science institutions can base their future resource calculations; support is a matter of government budgetary decision. The comments of Edwin L. Goldwasser, Deputy Director of the Fermi National Accelerator Laboratory, which houses the world's most powerful nuclear particle accelerator, reflect this concern:

> In order to plan effectively the activities of a basic research laboratory, it is desirable to have a substantial degree of stability in the support of the laboratory or, if not in the support itself, at least in the knowledge of what the support will be. Thus, if construction of a major research facility is undertaken, that commitment should be made only hand in hand with a concomitant commitment to support the use of that facility at some pre-established level for a reasonable number of years after construction is complete.

Wolfgang K. H. Panofsky, Director of the Stanford Linear Accelerator Center (SLAC), another FFRDC, described the situation he faces in even more specific terms:

> There are innumerable decisions which have to be made in the management of SLAC which imply commitments over many years. The simple approval of an experiment to be run in one of SLAC's beams initiates a chain of events from experimental design to final publication, which might take three to four years. Design and construction of a major experimental piece of equipment to be used at SLAC might span a three-year period.
>
> The total time over which effective exploitation of a key high energy physics facility comes to diminishing returns might be a decade or more, so that before then, either a major improvement program or a replacement program should be initiated. . . .
>
> The present funding cycle of the Federal Government is difficult to reconcile with the above timescale, unless it is accompanied with some type of "best-efforts" commitment, at least within the Executive Branch, that certain longer-range plans or guidelines are to be followed.

Government sector letters bring home the point that, at one time, Federal laboratories were regarded as stable institutions. These laboratories could depend upon a base level of funding from year to year, and were, at least in this respect, ideal for long-term efforts. What is of deep concern to the respondents is the unstable atmosphere allegedly created during the past several years by impoundments of funds, delays in the passage of appropriations, numerous reorganizations, and a variety of short-term policy shifts.

Respondents in this sector felt that in some ways Federal laboratories still provide a more sheltered environment for research than do extramural performers. Nevertheless, a conscious policy of limiting the size of the Federal payroll (as well as that of the FFRDC's), the Defense Department's decision to shift more of its basic research from in-house laboratories to extramural performers, and the overall pressures toward relevance and short-term payoffs in research policy have tended, in the opinion of the respondents, to place the basic research components of Federal laboratories and FFRDC's in a precarious position.

SUMMARY

By means of quotations, this chapter has illustrated respondents' concerns related to dependability in the funding for research in each of the major sectors of the U.S. research system. Respondents maintained that research, and especially basic research, whether conducted as an individual project or through the deployment of expensive resources in a large facility, requires dependability, stability, and continuity in funding in order to achieve maximum productivity.

Improved planning and policymaking for science and technology at the national levels especially for basic research is a solution frequently mentioned. Effective planning and policymaking would establish national priorities, facilitate coordination of research among various research sectors, and counteract the effects on R&D resulting from inflation, declining capital resources, and the Federal budget cycle.

More specific solutions proposed by respondents include multiyear commitment of funds for research programs, some form of institutional support, and tax incentives in order to stimulate industrial research.

VITALITY OF THE RESEARCH SYSTEM 4

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Vitality of the research system embodies a set of issues concerned with scientific and technical personnel and the institutional arrangements within which they carry on their work. While vitality related issues, as has been shown in Table 2-7, are spread throughout the research system, they were mentioned most often by respondents from universities, Federal intramural laboratories and independent research institutes.[1]

In the university sector, concern over an adequate supply of research manpower pervaded all levels of respondents. However, problems related to young faculty, tenure, dollar support for graduate studies, shrinking inflow of students, lowered levels of student quality and the growing competition between teaching and research were emphasized mostly by department chairmen.

Issues related to vitality ranked among the top three most frequently mentioned by directors of Federal intramural laboratories and by headquarters officials in Government departments or agencies. Limitations of Civil Service regulations on employment of scientists and engineers, the absence of positions for young scientists, and the provision of continuing education for older scientists and engineers are leading issues.

Independent research institutes discussed vitality in terms of the need for multidisciplinary research and the manpower requirements for such efforts.

[1] See Appendix E for rank-order tables.

In the industrial sector, major concern centered on the quality of new people. There was a feeling in industry that the best young people are not entering science and engineering fields; or, if they do enter, they are oriented toward university careers.

This chapter presents the views of respondents in the scientific community on the main concerns outlined above. For convenience, these concerns have been divided into four sections:

1. research manpower for the future,
2. opportunities for young scientists and engineers throughout the research system,
3. scientific and technical personnel management, and
4. national policy questions regarding scientific and technical manpower.

Also included in this chapter are some suggestions from respondents for dealing with the problems they discussed.

RESEARCH MANPOWER FOR THE FUTURE

Throughout the sectors of the U.S. research system—industry, independent research institutes, Federal laboratories, and universities—there is a convergence of concerns over adequate numbers and quality in research manpower for the future.

In the words of James M. Early, Division Vice President, Fairchild Research and Development Division, Fairchild Camera and Instrument Corporation:

Ten years from now in the absence of significant social changes, the supply of highly trained technical personnel will, from birth rate considerations alone, start to fall sharply. This effect will presumably add to the decreases in enrollment in the hard sciences and engineering which have occurred during the past decade. There may also be some reduction in the average natural and developed talent of those entering these areas. In fundamental areas such as language mastery, significant deterioration from past standards is currently evident. In California, average achievement test scores in mathematics as well as other subjects have dropped. When these limitations on the supply of personnel are compounded by decreases in the size of the age groups, there will be a real shortage of qualified personnel and an aging work force.

There may also be serious problems of motivation in that general social trends and the academic atmosphere at many universities motivate students away from industrial research and development. Coupling between universities and industry is in many cases poor, although less so in the engineering area than in the pure science areas. Historically, scientific productivity has been largest for younger workers and a continuing ample supply of highly trained, properly motivated newcomers is our best assurance of continuing high productivity.

Clayton S. White from the Oklahoma Medical Research Foundation, an independent research institute in Oklahoma City, was more specific about what attracts the best students today.

It is a truism not disputed by many, that the best talent among the country's youth is not moving into scientific research today compared with the case 15 to 20 years ago. Medicine and engineering, along with other professions, are attracting much higher caliber people than the graduate schools whose end product is the Ph.D. who will be manning tomorrow's research benches and populating the academic faculties of our many universities. Not only do I believe the best in talent is not being trained as professional investigators, but I doubt that those in training are, during their formative years, being given opportunities to develop the broad and diverse perspectives that can maximize research progress as the individual matures.

As seen by Hans Mark, Director, Ames Research Center, NASA, attracting the best minds to science is a problem which goes beyond the bounds of the Federal laboratories. He noted that fellowship money alone will not redirect the best talent.

In my view there is only one issue that transcends all others which must be resolved if we are to have the kind of basic scientific research we need to produce the intellectual capital which is necessary for the development of our technology. This issue has to do with convincing the ablest of our young people to pursue careers in basic research in the physical and biological sciences. I have noticed in the past eight or ten years a distinct drift of our very best people away from the basic fields. This is not to say that there are not many students today who are working in basic science. What I am saying is that the quality is not as good as it once was.

. . . Obviously, basic research should also be stimulated with money and some of the fellowships that have been cut back in recent years should be restored. However, I honestly believe that money is not the major issue. The most important problem is once again to convince our *best* young people to pursue careers in basic scientific research.

Typical of university responses concerned about research manpower for the future are the following excerpts. The first is from Albert H. Bowker, Chancellor at the University of California, Berkeley, who wrote:

Most certainly the nation will require a supply of scientists and engineers that is not only adequate in numbers but of the highest quality. In the past, universities have served as the primary source of such personnel going into the research sector by providing long-term support necessary for students to complete their education. However, there are some indications that the academic base and climate necessary to encourage outstanding students in the direction of science and engineering is in jeopardy. If the flow of talented students through the educational system and into the research sector is not to be interrupted or diminished, means and methods must be found to reinforce the values and institutions that support students in their long-term quest for knowledge. Universities provide the medium through which this can be accomplished but they must be fed by a sound system of secondary education and must have an outlet which provides strong, positive incentives for the competitive pursuit of excellence. My concern at the moment is that we may be entering a period in which uncertainty and confusion in the utilization (and underutilization) of present scientific manpower may have an adverse feed-back effect through the entire system that will be difficult to repair.

Another university respondent, H. S. Gutowsky, Director, School of Chemical Sciences, University of Illinois at Urbana-Champaign, related a reduction in graduate school enrollments to lower research output.

> . . . Movement of the "population bulge" through the universities combined with a leveling off or reduction in the rate of going to graduate school is already beginning to cut back visibly in the amount of basic research being done. The effects are modest so far, but could become large within a decade. The amount of basic research being accomplished will be reduced in proportion to falling graduate enrollments unless other components of the enterprise are increased concurrently.

The basic question regarding manpower supply was framed by a Vice President for Research and Development in a large manufacturing company:

> One issue of concern to all research is the decreasing number of people entering the sciences. How will we assure that young students are attracted to technical fields so that we will have an adequate reservoir of competency to carry on not only basic, but all types of research and development?

Recognizing that the supply of research manpower for the future depends almost exclusively on the graduate students in science and engineering, many respondents tried to answer this question in terms of graduate student support.

Typical of department chairmen, who ranked support for graduate studies fifth among their top eight concerns, is Rodney I. Clifton, Chairman, Executive Committee, Division of Engineering at Brown University in Providence, R.I. He discussed the problem of graduate student support and offered several specific solutions.

> Steps should be taken to ensure the attractiveness of research careers for the most promising students in each graduating class instead of allowing the "boom or bust" pattern of the past to continue. One step that would be particularly helpful would be to institute a highly selective fellowship program in which the faculty of each engineering school would be allowed to nominate up to say 5 percent of their graduating class for such fellowships. The pool of nominees would be reviewed by a national panel in each discipline who would select what appears to be the optimal number, say 2 percent. (Footnote: i.e., 2 percent of the total graduating class, not of the pool of nominees.) The fellowships should provide full support for up to four years of graduate education at the institution of their choice (preferably excluding the institution where they earn their undergraduate degrees unless a strong case can be made that this institution is uniquely suited to the student's research interests). Supplementary grants should be awarded to the institutions at which the fellowships are used in order to defray the additional costs of graduate education that are not covered by tuition.
>
> Another way graduate study could be made more attractive to U.S. students and more responsive to national needs would be to develop a program of combined governmental and industrial support of work-study fellowships. Such fellowships would support graduate students who would combine their graduate studies with work at the sponsoring industrial organization. Thesis research projects would be fundamental studies in fields that the industry is interested in. The fellow would not be under obligation to work for the industry upon graduation; however, if the relationship between the fellow and industry develops as

anticipated, then employment of the fellow by the sponsoring industry would occur frequently.

Relevant to the above suggestion for work-study fellowships are views from industry on university graduate curricula. Leonard Swern, Director of Technical Programs, Sperry Rand Corporation wrote:

> I spend a good amount of time dealing with universities and with the training of scientists and engineers. I have been convinced for some time that at many of the major universities, those operating at the highest levels of scientific competence, the main emphasis in the graduate scientific curricula is on the training of people who will, in turn, train other people. That is, the requirements for masters degrees and Ph.D.'s in the sciences emphasize university careers rather than industrial careers. Yet it is extremely important for industrial laboratories to have some of the best trained scientists working on problems of paramount interest to industry. As you well know, the technology of products such as computers and control devices, has advanced enormously. Industry needs practical, very well trained scientists to contribute to its new products in the industrial research and development laboratories. If graduate training conditions the best scientists and engineers to disdain an industrial career, then I believe the universities are not making an adequate contribution to the productivity of technically based industry.
>
> There is clearly a role for the National Science Foundation in this issue because the NSF has been an extremely vital force in shaping the programs at our universities.

Another suggestion for graduate student support also favors a specific form and came from Daniel D. Perlmutter, Chairman, Department of Chemical and Biochemical Engineering, University of Pennsylvania, Philadelphia. He suggested that graduate student support be independent of research grants to individual faculty members.

> It would be a great help if graduate student support were not made a burden on the faculty. Students ought to be supported because of a commitment to science and engineering education, not dependent on the fund-raising skill of a particular advisor. The research proposal would still ask for equipment, supplies, etc., as needed, but the dependent student would not be in such a precarious position.
>
> At least as important, the student with support could choose a topic on the merits of its scientific and policy aspects, rather than looking to its financial solvency. It would even be possible to do research on topics that are not formally proposed to a granting agency, freeing the researcher to move more into novel or untested areas.

Clearly, the future supply of research manpower was a major concern of respondents in all sectors. Often this led them to consider the numbers and the quality of graduate students as well as problems of support for graduate education. However, vitality is not simply a matter of graduate education and the respondents also had many ideas relating to scientists and engineers at career stages beyond graduate school.

OPPORTUNITIES FOR YOUNG SCIENTISTS AND ENGINEERS THROUGHOUT THE RESEARCH SYSTEM

Young Ph.D.'s and problems associated with their introduction into the research system were sources of concern to university department chairmen and to respondents associated with Federal intramural laboratories. Among university department chairmen, openings for young faculty and associated tenure problems ranked third among the top issues. Significantly, among headquarters-level Government officials, providing more positions for new scientists was part of their first-ranked concern.

Infusion of "new blood" into university science and engineering faculties as well as a balanced age distribution among the faculty are seen as increasingly difficult to realize. This problem was always mentioned among the top issues by department chairmen regardless of discipline or Carnegie Research University category. University presidents and vice presidents for research, however, did not give the same priority to this problem.

Typical statements made by respondents on the opportunities for young Ph.D.'s in the research system appear below. The university statements are first, followed by responses from Federal laboratories, Federally Funded Research and Development Centers (FFRDC's) and independent research institutes.

M. O. Thurston, Chairman, Department of Electrical Engineering, The Ohio State University, Columbus, focused on the problem.

> The current literature on higher education indicates substantial concern about reduced opportunities for younger people on university science and engineering faculties. The difficulties are attributed to declining enrollments, high fractions of tenured faculty, inflation, and particularly the rapid increase in the size of faculties ten to twenty years ago. Retirement rates are now low, and often those who retire are not replaced. The result is a non-uniform age distribution that will have an increasingly serious impact on the scope and quality of research in universities.

From a similar institutional perspective, John T. Jefferies, Director, Institute for Astronomy, University of Hawaii at Manoa, Honolulu, provided additional detail.

> The first problem arises from the recent rapid growth of many departments with many of the newly-created positions necessarily being filled with recent graduates. These people, in the course of time, have acquired tenured positions, thus tending to freeze the department into a mold from which, especially in a time of declining enrollments and decreased Federal support for science, it will be almost impossible to break out. The problem, of course, occurs in a context wider than the academic community. Early retirement, or encouragement for a career change, while no solutions, are avenues which might lead to some relief and the provision of opportunities for new graduates with fresh ideas. Much of the problem, of course, derives from the tenure system; I know that many universities are addressing this and some fresh ideas on that controversial topic might help to forestall the unhappy prospect of a department growing old together through 30 or more years of assured employment.

Emphasizing the problems of young faculty in science research and relating them to a university-wide context, Robert H. Strotz, President, Northwestern University, Evanston-Chicago, Ill., said:

> A major problem in university science research is one that is common with other areas of the university, but is probably of greater significance in the physical and biological sciences and engineering. This is the decreasing number of faculty positions available for new Ph.D.'s. While this is true in all areas in universities, the change from the expansionist 1960's is most marked in the sciences. The best of each year's crop of new doctorates tended to come to the university, with only a very few industrial laboratories being considered by them as almost equivalent. With the greatly decreased number of faculty positions available over the next few decades, this may cause a marked decrease in the number of very bright students going into fundamental research in science and technology. Certainly, the growing average age of the faculty will have a marked effect on the research and the teaching in these fields.

Typical of solutions proposed by respondents to the problem of young faculty in the university was that made by L. D. Quin, Chairman, Department of Chemistry, Duke University, Durham, N.C.:

> More openings for young people can be created if senior personnel are removed from the payroll at earlier ages. I do not mean early retirement by this; I suggest instead that a new type of award be made to a university department to recognize distinguished accomplishments of a senior member of the faculty, such award being of a magnitude to allow the university to hire a new assistant professor on the tenure track, several years before the opening of the "slot". Such awards would be rather like the present NIH Career Development Awards; my proposed "Career Accomplishment Awards" would simply come at the end, not the beginning of a career, but

the use of funds would not be greatly different.

In his letter, C. E. Hathaway, Head, Department of Physics, Kansas State University, Manhattan, suggested a two-fold approach to insuring the vitality of university science departments. His solution would insert younger people into the system and also address the problem of productivity of university science and engineering faculties.

> To alleviate this problem, there is a need for a two prong approach. Universities should be induced to consider early retirement for faculty. This early retirement should be sufficiently attractive so as not to punish retiring faculty. Such retirements could make room for younger faculty.
>
> In addition, a program should be initiated to encourage faculty sabbaticals. In particular, a program whereby NSF and universities shared the expense of faculty sabbaticals could provide sufficient inducement to universities such that a more realistic attitude toward the need for sabbatical leaves could evolve. A premium of value could be placed on sabbatical leaves aimed at training to enter a new field or subfield. This would encourage cross-fertilization, both within fields and between fields.
>
> Frankly, although I have listed the funding of fundamental research as the number one problem and an aging static faculty as the number two problem, the second may be the most detrimental in the long range. Funding of fundamental research can always be increased, but once a researcher begins to decrease in productivity, it is doubtful the same aggressive attitude of earlier years can be re-kindled.

As was mentioned earlier, respondents associated with Federal laboratories were also concerned about a relative lack of job opportunities for new graduates. Static or declining budgets as well as personnel ceilings were said to limit their ability to hire additional staff members. With the job market tight, relatively few people leave voluntarily, several respondents suggested, and laboratories tend to develop a staff "aging" problem. John E. Naugle, Acting Associate Administrator of NASA, put it this way:

> Severe personnel ceilings constrict mobility of scientists, discourage young people from entering research fields, and cause most laboratories to age—every year a year older. Young, recently trained people are the capital endowment of our technological society. We must replenish this capital at a faster rate than today's, by encouraging and assisting graduate education in the sciences, and making spaces for new graduates in research institutions.

His views were echoed by W. H. Tallent, Acting Director, Northern Regional Research Center, Agricultural Research Service:

> Personnel ceilings are preventing us from bringing in fresh talent right out of graduate school. With their very latest knowledge of scientific theory and practice and with their innovativeness not yet dampened by experience and maturity, these eager young professionals can be the very lifeblood of a progressive research staff.

It is interesting to note that respondents from FFRDC's did not stress these issues as strongly as directors of Federal intramural laboratories and agency officials.

Respondents from independent research institutes also spoke of a need to bring in new Ph.D.'s. For example, George Z. Williams, Director, Institute of Health Research, Institutes of Medical Sciences, San Francisco, noted:

> . . . there is no general support for bringing on new staff (particularly "unproven" younger scientists) and initiating new research pilot projects. Therefore, it is difficult to attract new scientists, even those with proven capabilities: They must accept the hazards of a time-restricted grant and the uncertainty of further support.

And Atherton Bean, Chairman, Mayo Foundation, Rochester, Minn., wrote:

> . . . a further consequence of this desire for rapid answers leads to increased allocation of funds for contracts and for center grants to the detriment of funding for basic biomedical research. In all of this, the young investigator is especially vulnerable, since support for research training waxes and wanes in unpredictable ways, and as

his career progresses, he tends to adapt his investigations to the sources of funding, rather than to the imaginative and creative research of his own choosing, on which the important scientific advances ultimately depend.

SCIENTIFIC AND TECHNICAL PERSONNEL MANAGEMENT

A few Federal laboratory respondents noted problems not only in bringing on new young talent, but also higher-level talent. The ceiling on Civil Service salaries was cited as precluding the recruitment of the best scientists for positions of leadership in Federal laboratories. This problem appeared particularly acute in the biomedical fields, where academic and industrial salaries are high.

The ceiling on Civil Service salaries is one element of a much larger problem described by a number of Federal laboratory respondents—what they see as incompatibilities between Civil Service regulations and procedures and the needs of R&D management. Attempts to control expenditures over the past several years are seen as having given rise to a number of practices severely limiting personnel management flexibility at the laboratory level. Directors of laboratories of the armed services, citing particulars of retrenchment actions, attributed these actions to overall DOD policy to reduce the share of basic research conducted by intramural DOD laboratories and to increase the share done by extramural performers. In a lengthy, detailed critique of new Navy regulations aimed at reducing the Navy's intramural science and technology base, J. T. Geary, Director of the Naval Research Laboratory, described how those regulations have created, in his view, "an environment which tends to frustrate rather than enhance productive R&D":

> Specifically, these policies impose ceiling limitations irrespective of the work requirements, the responsibilities, and the competence of a laboratory. . .
>
> Although average grade, high grade and supergrade limitations are designed to prevent so-called grade "creep" prevalent in the civil service, this policy when applied to Navy laboratories fails to recognize that quality, innovative R&D is dependent on the highest individual competence. In order to foster this competence, managers must have the capability and freedom to create a career pattern competitive with other institutions and commensurate with the quality and stature of the individual. This is in direct contrast to the typical bureaucratic institution with fixed organizational positions, which rely much less on individual creativity.

Personnel ceilings, grade restrictions, and Civil Service regulations are all elements of the larger problem of maintaining a creative research environment in Federal laboratories and hence insuring vitality. As I. A. Wolff, Director of the Eastern Regional Research Center, Agricultural Research Service, described it:

> Older standards of excellence have in many places given way to an 8:00 a.m. to 5:00 p.m. syndrome. Standards are lowered, a phenomenon that can begin in educational institutions. As a response to the anti-science attitude of the last several years some scientists themselves are becoming more inflexible in their thinking. We must try again to recreate the excitement of personal discovery, the satisfactions of basic achievements, and the kind of research groups that reinforce accomplishments possibly understandable only within the scientific community. The public image of scientists must be elevated to keep topnotch individuals in basic research yet permit them adequate ego-satisfaction and monetary returns.

The personnel management problems of Federal laboratories have their parallels in other sectors of the R&D community, although they are manifested elsewhere in somewhat different forms.

On the environments for creative scientists and engineers, Mark Shepherd, Jr., President, Texas Instruments, Inc., wrote:

> In my judgment, the most productive mode of

operation for creative scientists and engineers doing research in industry is to be coupled (but not overcoupled) to the requirements of the operating organizations. I have had the opportunity to observe performance in situations where the research laboratory was totally decoupled from the perceived needs of the Corporation, yielding a highly unproductive and random output. It should be noted, however, that a possible danger of coupling is that long term, highly speculative research tends to suffer, since speculative longer term work is more difficult to manage, judge, and be patient with.

Regarding scientific and technical personnel, Kent Kresa, Vice President and Manager, Northrop Corporation, Hawthorne, Calif., raised the general problem of technological obsolescence and offered several solutions:

> New and improved techniques emerge which make the more mature technology obsolete, and along with this obsolescence, is a subset of highly trained professionals who have worked in that specialty since its inception, but do not have the capability nor the desire to begin anew in another discipline. I foresee no easy solution here, except for massive reeducation programs or early retirement.

Finally, regarding the practioners of R&D, David Langmuir, Research Consultant, TRW Systems Group, Santa Monica, Calif., remarked about the ways scientific and technical people appear to have changed.

> I think that the motivations of researchers have shifted in the past half century from a mixture of predominantly love and fame to a mixture heavily weighted with wealth and power, and that this has been more obvious to people outside the ranks of scientists than to those within. I do not think we will find our proper role in the big picture until we think and speak more precisely about it.

NATIONAL POLICY QUESTIONS REGARDING SCIENTIFIC AND TECHNICAL MANPOWER

Some relationships between long-range planning for science, national manpower policies and Ph.D. programs were discussed by F. N. Andrews, Vice President for Research and Dean of the Graduate School at Purdue University, West Lafayette, Ind.

> In the 1950's, we began a nationwide program to increase our supply of scientists and engineers. It is my own observation that this was highly successful, that we did indeed train people in many disciplines at a very high level, and that advances in the sciences and engineering have been of great benefit to the nation. Since then changing political and economic conditions and changes in population growth have had a profound effect upon all major research universities. In some disciplines the job market for Ph.D. trained individuals is poor and is not likely to improve. In some disciplines the decreased graduate school enrollment suggests that we will in the fairly near future be facing shortages of highly skilled individuals. A long-range plan for science would give some guidance to planning for advanced study. We appear, for example, to have an oversupply of astronomers. Obviously, we should not start new Ph.D. programs in this area, but we do need to train some minimum number of new people to replace those who retire.
>
> Manpower projections for new disciplines are almost impossible to achieve; therefore, we must have some kind of a base which will permit new sciences to develop and flourish. Forty years ago we had no idea how dependent we would be on high energy physics, and solid state physics, to choose only two examples.

Apropos of national manpower considerations Mark Shepherd, Jr., President, Texas Instruments, Inc., Dallas, Tex., called for a solution to "the frequent temporal mismatch" between the supply of and the demand for advanced degree graduates:

> Another serious problem is the frequent temporal mismatch in quantity between supply and demand of advanced degree graduates from the universities. Moreover, the dislocation of bright, young, creative, technical people brought about by shifts in the economy and termination of job assignments has a profound effect on *them*. Unquestionably, this mismatch is causing the nation problems today, and will cause problems

in the future. We must invent some sort of shock absorber to mitigate the effect that I am describing.

Also, according to W. Dale Compton, Vice President, Scientific Research, Ford Motor Company, without a coordinated national manpower policy, changes in funding patterns can produce dislocations in university research programs and thereby alter the availability of new talent for industry.

> The source of funds inevitably influences how many students can be trained in an area. While it is true that the training of students in fields of low priority is to be discouraged, changes in research direction frequently occur in a time frame in which the educational system cannot respond. For example, we have moved quickly from emphasizing materials to energy in our research funding, but there appears to be little planning on the part of any of the agencies on how to accomplish this without causing major dislocations to the graduate research activities. I would strongly recommend that serious consideration be given to finding a way to stabilize the long-term research needs of the university training programs upon which we are all dependent for new employees, without making them subject to the rapid fluctuations that occur in the research missions of the agencies.

Addressing himself to a different aspect of national manpower policy, James Hillier, Executive Vice President, Research and Engineering, RCA, discussed what he sees as Government-induced inflation in the cost of professional and technical manpower.

> The dominant cost in any research is the cost of professional and technical manpower. This cost is determined by a relatively free market, that is, it responds to the balance of supply and demand. Unfortunately, the supply can respond only slowly to changes in demand due to the long period (6-9 years) between the point when an individual commits to a professional career in science or technology and the time when he enters the market. The Government has tended to ignore the dynamics of the system in the planning of its technical programs. The growth of military and aerospace R&D created a demand for professionals that greatly exceeded the capability of the system to supply them with the result that the rate of increase of cost substantially exceeded the national inflation rate. Similarly, the rapid and highly publicized reduction in aerospace engineering greatly reduced engineering enrollments. The resulting artificial shortage is just now moving into industry. This, by itself, is inflationary.
>
> Unfortunately, there are strong indications that the Government will make matters worse by its stepped-up programs on energy research. I recognize that the primary effect is in engineering. However, in industry the inflation rapidly spreads into the basic and exploratory research areas. The result is a steady reduction in the annual effort that is roughly equal to the difference between the national and professional inflation rates. The total industry reduction is greater because of the abrupt discontinuance of basic and exploratory research when the steady reduction takes the effort below the "critical mass" or the fortunes of the company require it to "defer" noncritical expenses. Either case is tantamount to permanent termination.

The above paragraphs typify respondents' concerns related to national manpower policies for scientific and technical personnel.

CONCLUDING REMARKS

This chapter provides views from each research sector on the role of scientific and technical manpower and the role of institutional environments in maintaining the vitality of the research system. Representative views appear for most of the major issues and problems concerning vitality. Suggested solutions to the issues and problems appeared in about one-third of the letters. Table 4-1 lists some of these solutions. Frequently these suggested solutions were mentioned without any elaboration. In cases where no solution was offered respondents often said they saw no solution or that any meaningful solution would require further analysis and study by the scientific community and the public.

Table 4-1. Some Suggested Solutions from Respondents for Issues Concerning Vitality of the Research System

Issue Group	*Federal Laboratories*	*Independent Research Institutes*	*Industry*	*University*
Research Manpower for the Future		Separate graduate educational objectives from research objectives.	Stabilize training support (whether as fellowships, traineeships or research support) in order to ensure a predictable output of Ph.D.'s for industry.	Revitalize high school science. Provide teaching support fellowships for top students. Activate graduate traineeship program. Prepare flexible, interdisciplinary oriented students with education and research programs along interdisciplinary lines.
Opportunities for Young Scientists and Engineers throughout the Research System	Permit Federal laboratories to hire basic research scientists in a new category of appointments outside Civil Service		Overhaul academic world to nurture and develop creativity.	Place more young scientists on agency review panels. NSF should support studies on aging, static faculty and possible new structuring of faculty positions
Scientific and Technical Personnel Management	Provide greater flexibility in personnel management under Civil Service regulations.		Provide massive re-education programs or early retirement to avoid problems of technological obsolescence.	Abandon tenure system. Develop specialized research centers as new organizational experiments for separation of education and research.
National Policy Questions Regarding Scientific and Technical Manpower	Operate more Federal laboratories as FFRDC's	Develop program of national science research fellowships to insure job continuity for scientific personnel in the face of fluctuating Government objectives. Enhance creative role of researcher by decreasing the role of RFP in basic research efforts.		Identify new areas where future scientists will be needed.

FREEDOM IN THE RESEARCH SYSTEM 5

FREEDOM IN THE RESEARCH SYSTEM 5

Freedom of inquiry is a value that has traditionally been associated with science. The right of the scientist to choose his own line of research and follow it wherever it may lead is widely defended as being desirable or even necessary for the fruitful development of scientific knowledge. Several of the letter respondents expressed this view. Moreover, it has long been accepted that science should be free of interference from government. These rights were established early in the history of modern science, as the new scientific community gradually won its struggle for recognition.

The respondents mentioned a number of ways in which they find that the contemporary situation departs from the ideal of completely free inquiry. For example, in the industry sector there was special concern that inflation, a declining availability of capital, and the need to solve immediate problems are restricting industry's ability to conduct basic research.

Usually, however, the loss of freedom in doing research was attributed to actions of government. The problem, as it was reported, stems largely from the dependence of the different sectors on government research support. This dependence may not be part of the classical picture of free scientific inquiry, but it is a present reality. Two results of it were widely perceived. First, the fields of research in which support will be provided are limited by public policy and the particular policy of the granting agency. In fact, a great deal of concern was expressed about pressures to do targeted or applied research rather than basic research. Such pressures were reported particularly by the Government and university research sectors, where the dependence on research support from government is quite strong.

The other result of depending on government support is what was widely felt to be overmanagement or overregulation of research by government. Again, this problem was expressed frequently by the Government sector, where there is direct budget control by a Federal agency, and consequently a great deal of direct management. In the universities, where government support takes the form of research grants and contracts, there was concern over the amount of paperwork that is required in connection with such support, and also with regulations governing the actual conduct of research. Although most research in industry is not funded by government, this sector also reported very frequently that government policies and regulations are hindering their basic research effort.

It will be convenient, therefore, to divide the following discussion of freedom in the research system into two parts. The first will deal with the pressure to do applied rather than basic research, as it was reported by each sector. The second part of this chapter will similarly deal with problems pertaining to overregulation of research by government.

PRESSURE FOR APPLIED RATHER THAN BASIC RESEARCH

University

Of all the issues that were raised by university respondents, this is the one that was mentioned most often. One statement of this issue came from President Dale R. Corson of Cornell University:

> The first problem I want to mention is what I perceive as a growing tendency of government to target the research it sponsors on short-range, high-payoff objectives, to the detriment of both longer-range needs and the education process. We have moved away from the support of people, including students, and away from investment in the future.
>
> Specifically targeted research, typified by relatively short deadlines and by the request-for-proposals procedure, is not well suited to university research and the training of young scientists. Whatever happened to the old notion that the very best people should be identified and then given an opportunity to explore the leads as they see them?

The above reply proposes that one of the damaging effects of the pressure for applied research is its effect on the educational process. There is a specific effect on the faculty and their research, according to Eugene H. Man, the Dean of Research Coordination at the University of Miami:

> The drive toward short-term, problem-oriented research in academic institutions is already showing the potential it has for becoming a corrosive factor in this University's capacity for conducting fundamental research programs. Faculty are caught between two pincers: the lure of funds available for producing rapid answers to immediate problems, and the erosion of support for more basic, long-range research. Further, the support continuity for long-term research is missing.
>
> We see our most talented faculty, responding to the need to keep research programs and organizations intact, moving toward less fundamental areas because of the lure of more certain funding. The eventual result, if this trend continues, will be that our national reservoir of talent for developing the fundamental concepts, on which *all* applied research must ultimately feed, will become depleted.

Dean Man here shows how freedom in research can be related to stability of funding and the need to maintain the supply of capable scientists, which are issues discussed in previous chapters.

These two replies suggest that overemphasis on applied research is shortsighted even if one is interested in getting practical results. The respondents generally were not opposed to applied research in itself, but they insisted that basic research also is necessary to guarantee the production of useful technology in the long run. This view is illustrated by the comment of George A. Russell, Vice Chancellor for Research and Dean of the Graduate College at the University of Illinois:

> A careful analysis of successful solutions to some of the major problems this nation has faced in the past, whether it be in food production, communication, transportation, medicine, etc., will reveal two essential ingredients for success: a core of basic knowledge, generated in most cases from "non-relevant" research, and a cadre of well-trained individuals who can extend and expand or re-direct their fundamental research to the solution of the pressing problems of the time. In the corn country of Illinois, we do not today reap 150-200 bushels of corn to the acre because we set this as a goal, and did "relevant" research to achieve that goal, but because basic "non-relevant" research in plant genetics helped to obtain the fundamental insights needed to make the slow but steady progress in agricultural technology that was required.

The views seen so far came from university presidents and vice presidents. Table E-1 of the Appendix shows that these respondents mentioned the pressure for applied rather than basic research more frequently than any other issue. That is true for both Carnegie Research Universities I and Universities II. It is also true for department chairmen. However, there were certain classes of disciplines, engineering in particular, in which the chairmen did not rate this issue as first. Engineers actually rated it quite low.

The responses from chairmen illustrate this issue from a perspective that not only is closer to the actual research work, but also is conditioned by the problems of individual disciplines. As an example, from the Division of Biological and Medical Sciences at Brown University, Dean Elizabeth H. Leduc wrote:

> Our "number two problem" is that of low faculty (investigators) morale. This is the result of a general malaise based on recent changes in the Federal system of support for biomedical research which can be summarized very briefly as follows:
>
> - Shifts in program emphasis to specific targeted research, primarily on cancer and diseases of heart and lung, with resultant diminution of research support for other areas of biomedical research;
> - Concomitant emphasis on rapid translation of research results to clinical applications, suggesting a competition for funds between fundamental research and health care. . . .

Another chairman's view came from Earl Hunt, Chairman of the Department of Psychology at the University of Washington, who stated:

> The second problem that Psychology faces, at the institutional level, is that Psychology is, and always has been, under heavy pressure to "make our research relevant" before the necessary scholarly knowledge base has been established. I could make an excellent case out for the proposition that the current mess over intelligence testing arose for precisely that reason. I am concerned that such pressures are increasing. In particular, agencies of the federal government seem to have more and more money for programs that promise "results now," and less for the slower but safer route of establishing scientific facts before offering social engineering advice. In this respect some of the current policies of NIE and NSF are disturbing.

Similarly, the chairman of a physics department reported that one of his faculty members is a recognized expert in nuclear physics. Although he is eager to work on a theoretical problem in that field, he is working in another field where funding happens to be available.

Government

In the Government research sector, the increased emphasis on short-term rather than basic research was again a major issue. Among all these respondents combined it ranked second, while it was actually first among directors of intramural laboratories and headquarters officials. Here again, the issue is often expressed in terms of pressures for targeting and short-term payoffs in research, and a bias against longer-term more fundamental efforts. For example, W.N. Hess, Director of the Environmental Research Laboratories (ERL), of the Department of Commerce's National Oceanic and Atmospheric Administration stated:

> The major issue related to fundamental research, as I see it for a laboratory system such as ERL, is to achieve and maintain a proper balance between short term and long term research. . . there is strong pressure on our research programs to focus efforts on providing short term results. . . .

The implications of this trend were noted by many respondents, including William W. Carter, Acting Technical Director of the Harry Diamond Laboratories, U.S. Army:

> With the lack of a strong, clear federal policy on fundamental science, and a national anti-science climate, Congress and others are pushing too strongly the short term, applied research emphasis. We are out of balance and will pay the consequences in the 1980's. It is exceedingly difficult to protect and fund even small groups of basic researchers for the extended times that are needed to produce significant results.

The phrase "pressure towards research with short term payoffs" recurred with considerable regularity among the responses. Again and again, laboratory directors spoke of the difficulties of sustaining basic or long-term research in the face of these pressures, and expressed the desire to establish a balance, so as to assure "replenishment" of the stock of new knowledge for future applications.

Industry

The respondents from industry were also concerned about an increased emphasis on applied research. In fact, this was a major concern of theirs. As Table E-2 in the Appendix shows, the third most prevalent issue mentioned in the industry sector is the perception that short-term relevance is becoming the only objective of research. In addition, the table shows that there are other issues from this sector that have to do with an alleged shift away from fundamental research.

The problem of short-term relevance was mentioned particularly often by vice-presidents or directors of research. For example, C. J. Meechan, Vice President for Research and Engineering at Rockwell International, said that:

> The formidable challenges which the nation faces (in areas of energy, resources, environment, food), in conjunction with limitations on financial resources have forced many basic research workers into activities aimed at short-term solutions to these problems. The lower priority given to fundamental research restricts and inhibits the scientific freedom necessary to attract highly motivated, skilled researchers into promising areas. In addition, it promotes a lack of funding continuity, which makes it difficult to establish and retain the necessary sophisticated teams required to efficiently carry out substantial projects. The subsequent instability and disruption creates longer term problems in attracting and motivating top quality scientific talent and skilled research managers.

This response from industry sounds very much like the university letters previously quoted, where the pressures on individual researchers are emphasized and the connection between loss of freedom and instability of funding is brought out.

In the above quotation, two reasons are given for the shift to applied research. One is the new and formidable problems that the Nation faces. The other is limited financial resources. Other respondents elaborated on this latter point by indicating that businessmen can no longer count on capital being easily available on a long-term basis. Hence there are more short-term applied projects, as opposed to long-term basic and exploratory projects. An example of this view is the statement of James Hillier, Executive Vice President, Research and Engineering, at RCA Corporation, which was quoted in Chapter 3. For him, there is a close connection between the issue of declining availability of long-term investment capital and the present issue, declining freedom to do long-term, basic research.

Some respondents traced the pressure for applied research to policies of the Federal Government. An example is the statement by D. J. Blickwede, Vice President and Director of Research for Bethlehem Steel Corporation:

> At the national level, our goals for science and technology have become mission oriented. That is, the objective of much of the research being funded by the Government through NSF, etc., is aimed at solving specific National problems. In this regard, emphasis has been placed on socio-economic programs at the expense of basic research in the pure sciences.
>
> The result of this trend. . .is to markedly reduce the Nation's basic research effort in the short range, and in the long range to seriously jeopardize our position of world leadership in science and technology.
>
> As a solution to this problem, I believe that we should de-emphasize mission oriented research and return to funding programs aimed at the advancement of knowledge, particularly in science and technology. It is knowledge of this type that ultimately is utilized by American industry and which has been responsible for our position of world leadership.

This also is similar to the many letters from universities and Government laboratories that see the problem as one caused by a policy of government. In fact, there were industry respondents who took the same point of view as those university respondents who deplored pressures that government places on universities to do applied research. The statement from George L. Pake, Vice President of Xerox Corporation and Manager of the Palo Alto Research Center, illustrates this:

> I believe there is no doubt in anyone's mind that the federal agencies, with congressional and possibly even public support, have been pressuring the universities in more applied directions. Here I feel my experience in both sectors, i.e., universities and industry, is of some value. Basic science is what universities do best. Applied research and development is what industry does best. It is not easy to justify to stockholders large expenditures on basic research that is just as likely to be applied by a competitor as by my own company. Universities on the other hand cannot solve real-world problems because they have no inherent requirement to solve such problems. As an industrial research manager, I depend on universities to build the fundamental science base from which my research scientists can draw in solving applied problems for Xerox.

This broader view reinforces what many university respondents themselves said—that the university is the place for basic research, and that the level of such research at universities should not be diminished.

Independent Research Institutes

Many respondents from the industry sector were concerned that a decline in basic research can have harmful effects on the competitive position of American industry and even on the leadership role that this country plays in the world. A very similar concern was expressed in the independent research institutes, where over-emphasis on applied research ranked seventh among all issues mentioned.

Thus, the following opinion was expressed by Martin Goland, President of Southwest Research Institute:

> The second issue I would like to raise is the obvious one of the reduced national recognition of the importance of basic research. The combination of changing public attitudes and the reduced resources available to research because of the economic recession, has caused a marked reduction in the amount of fundamental research activities being undertaken. It is imperative that the current atmosphere which downgrades fundamental research in favor of directly relevant and applied tasks be counteracted.
>
> The gradual erosion of our national research capabilities in comparison with the other nations of the world could pose severe problems, in my view, to our future social and economic viability. I shall not bore you with the arguments which I am sure are already familiar to you regarding the reliance we place on our technological strength to insure that American industry remains the most competitive and cost-effective producer of goods and services. The flow of new ideas which come from fundamental research is the obvious catalyst which enables us to maintain our leadership position.

OVERREGULATION

Industry

Of all the issues mentioned by industry respondents, the one brought up most often was government regulations and controls. This is shown in Table E-2 of the Appendix. A broad statement of this issue came from Frank H. Healey, Research Vice President of Lever Brothers:

> Regulatory actions are compounding at an alarming rate—arising not only from new legislation—but from the creation of federal, state and city agencies with powers to promulgate new and broadened regulations. The Food & Drug Administration (and its O-T-C panels), the Consumer Product Safety Commission, the Occupational Safety and Health Administration, the Environmental Protection Agency and the Federal Trade Commission all are actively proposing or issuing regulations affecting the technology of consumer product companies. New testing methods, new criteria for safety and efficacy, new environmental requirements all add to the time, effort, and cost of developing new or improved products. Often these criteria change or are in conflict. If this trend continues, the risk and capital involved in developing and in-

troducing any new product may become prohibitive for all but the very largest companies. The effect can then lead to elimination of long-range research since no pay-out can be anticipated.

B.L. Williams, Director of Corporate Research at Monsanto, was more concerned about consistency of regulations. One of the problems he listed is "The inconsistency of government regulatory actions or proposed actions."

> It is not the regulations themselves or the threat of regulatory action, onerous as they might be, but the unpredictability of such action. The unpredictability tends to push deployment of resources toward fighting real or possible "fires." Fire fighting might require basic research, but it is not likely to be predominantly long range. This is particularly true in product and end-use regulation, as well as what basic raw materials will be economically preferred in the 1980's. These concerns require generation of more options than in the past for defensive purposes.

Of all the consequences of overregulation, one of the most serious, according to the industry letters, is that research resources are diverted from basic research to "defensive" research, i.e., research designed to insure compliance with the regulations. This is clearly the opinion of Lee A. Iacocca, President of the Ford Motor Company:

> Long-range research on problems of concern to major U.S. industries is essential to the maintenance of a technological base that will permit the U.S. to remain competitive in the world economy. Although part of the drastic decline in industrial support for such research is a result of the depressed economy, another serious cause is the need for industry to commit a substantial and increasing proportion of its research resources in response to regulatory demands and goals established by the Congress and a number of federal agencies. Research is needed to develop sound technical solutions to environmental and safety problems, but some present and proposed regulation is excessive, and research to meet such goals wastes scarce research resources. In these cases, resources could far better be spent on long-range research that will provide improved products or processes.

The same point is made by Herbert E. Hirschland, Vice President for Technology and Development of the American Can Company:

> Fundamental (long term, basic) research has classically been a small percentage of total industry research. Nevertheless, it has been important and there are certainly many examples well known to all scientists. Industry has been more concerned with applied or developmental research, again for reasons well known to the scientific community. Our fears are that the last vestiges of industry's fundamental research, as well as the related efforts in applied research, will take a back seat to research related to compliance. While we must be careful not to portray an image of being anti-environment, anti-pollution, anti-consumer, anti-general societal benefits, the cost of R&D associated with government regulations, as well as the cost of coping with all of the requirements, per se, is increasing dramatically.

In the view of Richard A. Greenberg, Vice President for Research and Development at Swift & Company, this deflection of productive research funds into "defensive" research depends closely on the public's attitude toward science and technology. He felt that both Federal regulatory agencies and the Congress are acting defensively because of public pressure. As a result, their actions are impeding, rather than promoting, technical advance. The situation, in his view, has reached crisis proportions, and must be reversed. The National Science Foundation must spearhead a program to inform the public of the "virtues" of technological advance, in order at least to put its potential negative aspects into perspective.

There is one aspect of the overregulation issue that is peculiar to industry. A fair number of letters expressed concern about Federal patent policy and antitrust legislation, maintaining that these are hindrances to research. J. H. Gross, Director of Research at the United States Steel Corporation, expressed this view:

> Present patent laws are not particularly generous when one considers the length of time required to bring a new technology to useful status. Rather than improve exploitation of patent rights,

> pending and proposed legislation make acquisition and maintenance of patents so difficult that they approach confiscation of privately developed technology in fields considered to be crucial to the "public interest." This philosophy can do nothing more than discourage investment in major high-cost, high-risk research programs.

On the subject of antitrust legislation, he added:

> Even if patent protection provided appropriate incentives, many projects envision development costs beyond those that can be underwritten by even the largest corporations. Such research could be undertaken on a consortium basis to permit tolerable financing and to avoid costly duplication of effort. However, precedents suggest that this approach could be subject to challenge under the anti-trust laws. This problem can be eliminated by consistent, understandable guidelines as to the Federal Government interpretation of the application of the anti-trust laws to joint research and development projects or through new, more liberal legislation.

Government

In the Government research sector, overregulation was also felt, but in a different form. Since these laboratories are directly managed, or at least funded, by the Government, their concern was with overmanagement, or too many restrictions imposed by higher administrative levels. This issue ranked third among all respondents from this sector combined, and was actually second among FFRDC's as Table 3 of Appendix E shows. In view of the open-ended manner in which the questions were posed to the respondents, the similarity between many of their statements is remarkable, and suggests the existence of widespread and deep concern. Two examples will illustrate the flavor of this concern. J. E. Colvard, Technical Director at the Naval Surface Weapons Center, wrote that:

> The major problem I see facing research in the near future is "over management by multiple levels of review." This over management so overwhelms the other problems that it makes them minor.
>
> . . .The dollars appropriated for research are adequate. The dollars expended on research are inadequate because so many of the dollars are spent in reviewing and managing the research.

From George H. Vineyard, Director of the Brookhaven National Laboratory, came the statement that:

> Among many critical issues, in addition to the perennial question of funds, I would single out these:
>
> 1. At what level should the primary responsibility for directing research programs reside?
>   Should it be with the individual scientist and his institution, or should it be in Washington?
>
> The first issue arises because of the strong tendency for research to be directed more and more from Washington. As public concern with technological issues has increased and as this concern has been reflected in Congress and in the Federal agencies, tighter management from above is being imposed. In this Laboratory, for example, the degree of detailed involvement of our principal sponsor (ERDA) in setting priorities and determining the nature of each research program is rapidly increasing, and no limit is in sight. Along with this, our budgets become ever more fine-grained and detailed.

Vineyard adds that ERDA has been made aware of this problem and is reviewing it. Another laboratory director spoke of "pragmatic micromanagement"; while elsewhere it was termed "excessive program control"; or "management of, control of, influence on, and guidance of science by *nonscientists*." All these directors seemed to have in mind the same problem: decreasing autonomy of their institutions, *vis-a-vis* their parent or sponsoring agencies, OMB, and Congress. The views of the laboratory directors on this issue, furthermore, were shared in higher levels of their agencies, a fact evidenced by the letter of John Naugle, Acting Associate Administrator of NASA. Naugle, taking a perspective sympathetic to the laboratories, discussed the "problem of overdirection of basic research," and observed that:

> Basic research is severely restricted by the application of management techniques that have been used on highly specific project activities.

The need for detailed advanced planning of research was seen by Naugle as reducing the freedom of inquiry of the researcher and forcing him into more conservative paths. In addition, others stated that it absorbs a considerable fraction of the time and energy of researchers and thus detracts from the effort that can be devoted to the research itself. At the institutional level, such planning generally entails the subdividing and compartmentalization of budget categories. This in turn was said to increase administrative overhead, and reduce the laboratory's ability to organize its resources so as to respond to opportunities which may appear between budget cycles. In addition, excessive external direction was often felt to reduce the coherence of a laboratory's program—the special strength it derives from operating a set of inter-related activities. This allegedly transforms the laboratory into an instrumentality of higher administrative levels (a "job shop") rather than an entity with an organizational logic of its own.

Part of the tendency toward stronger centralized control of research, in the minds of some respondents, is a growth in the bureaucratization of Government R&D. Red tape and unnecessary administration were particularly mentioned by the respondents. Witness, for example, the words of Harold M. Agnew, Director of Los Alamos Scientific Laboratory:

> The ever increasing bureaucracy composed of managers who require more and more detail, justification, and guaranteed schedules, will in the not too distant future completely eradicate our Nation's world position in research and technology. Bureaucratic regulations and requirements for conformity will stifle basic research. Bureaucracy will eradicate creative endeavor and innovation in the long run. Bureaucracy eventually loses sight of what the real original objective was and becomes only concerned in its own management and control functions. Unless this trend toward centralization is somehow reversed I predict the U.S. will rapidly lose its lead in science and technology.

Independent Research Institutes

Among independent research institutes this concern about increasing bureaucratic controls was also expressed. For example, from the American Institutes for Research in the Behavioral Sciences, President Paul A. Schwarz wrote:

> *Problem #2* is the growing red tape associated with the preparation of proposals and the management of research. We have no quarrel with the objectives of tight financial safeguards, and certainly not with the growing concern for individual privacy, for legitimate rights to information, for other social goals. But each of these entirely worthwhile objectives loses much in the instrumentation. Again, the needs of the bureaucracy for stipulating, monitoring, and quantifying seem to take precedence over the initial objective, which gets all but lost in the comfortable rigidity of the mechanics. We are especially distressed by the growing introduction of procedures that were motivated by notorious excesses in commercial enterprises quite different from ours, which are applied willy-nilly to all, and have no effect whatever except higher costs of administration. We suspect that a complete overhaul of the proliferated requirements and a greater reliance on peer control mechanisms could markedly increase the productivity of research, in devoting more of the research dollar to science and less to incidental administration.

This recalls the statement from the industry sector that the cost of compliance with regulations comes out of the research budget, and thereby diminishes the amount of genuine research. In the independent research institutes, this issue ranked fifth.

University

In the universities, the aspect of overregulation most often mentioned was the increased demand by government bodies for accountability. This was the fifth-ranking issue among presidents and vice presidents (combined) from Carnegie Research Universities I. One of these officials stated the issue in this way:

> One of the problem areas adversely affecting the productivity of working scientists at Rutgers, and presumably at many other state universities, is the faculty response to the institutional need for greater public accountability.
>
> Such accountability, initiated by state governments for a variety of reasons, but basically financial, while reasonable in intent, has generated a variety of management devices, some imposed by the State and others created by the University which tended to shift faculty emphasis from quality to efficiency in education and scholarship.
>
> The management devices used include formula and program budgeting, more elaborate justification of specific programs, reordered allocation of resources as well as much closer monitoring of faculty time and work loads. The emphasis on faculty work loads has resulted in a squeeze on available time which adversely affects both teaching quality and research productivity. In addition, monitoring of faculty time has created a trade union atmosphere which has a deprofessionalizing effect on the faculty with a consequent reduction, in my judgment, on creativity. Of course, accountability is necessary, and in some respects it has had a salutary effect on the faculty, but as an overview in the manner it has been addressed at Rutgers I believe it has had and will continue to have detrimental effects on research productivity.

This is from James W. Green, Acting Dean of the Graduate School at Rutgers. Although the above comment was in terms of the demands of State agencies for accountability, the problem was not seen there alone. For example, William F. Massy, Vice Provost for Research at Stanford University, had these concerns about Federal demands for accountability, and Federal regulations in general:

> The second critical issue is the reduction in research productivity due to the increasing number of complex and uncoordinated federal regulations that have been hitting research performers.
>
> The impact of this is to drive upward the costs of compliance with executive orders and contract provisions unrelated to the work statement in the research proposal. This leads to increased direct charges on grants and contracts as principal investigators add people to deal with these regulations and the ancillary requirements put on by the University's administration in order to meet its obligations and keep risks at a tolerable level. In addition, the University's indirect costs go up for the same reasons.

Massy here adds some quantitative information. During the period from 1967 through 1974, he states, the indirect costs of sponsored research, instruction, and departmental research at Stanford grew at an average real rate of 3.4 percent. The general and administrative component of these indirect costs grew at a real rate of 5.9 percent per year. At the same time, the real direct expenditures for all research and instruction actually declined at an average rate of 1.5 percent. Much of this increase in general and administrative costs at a time of decreasing direct costs he attributes to externally imposed requirements. Examples include increased demands for accountability, more complex requirements and litigiousness in the employee relations area, affirmative action, and miscellaneous requirements of the Federal procurement process. This increase occurred in spite of a successful effort by the University to decrease its overall general and administrative budget during the same period. Massy goes on to say:

> In addition to out-of-pocket costs, scarce faculty time is increasingly being allocated to coping with externally imposed regulations not related to the scientific effort needed to perform the research. Examples of individually worthwhile but cumulatively burdensome requirements include: ever more extensive and complex human subjects reviews; animal care regulations; health, safety, and radiological hazards review and certification; affirmative action; and (potentially) increased requirements for property control and faculty time and effort reporting and documentation. Coming at a time when indirect cost rates are rising (due to the reasons set forth above) and

research funding is harder to obtain there is a danger that these pressures will cause potentially productive scientists to opt for "easier" but less meaningful lines of research that do not require government sponsorship.

We emphasize again that many of the changes that have occurred during the past few years are individually meritorious. However, their cumulative effect is to divert substantial sums out of the doing of research and into its administration. There is also a disturbing tendency to promulgate tight regulations with broad applicability to take care of situations that have been identified as occurring in a few cases. In other situations the ills that are sought to be corrected may be more imagined than real. We believe that there is an urgent need for evaluation of the cumulative effect of federal regulations and accountability requirements vis a vis research, and upon the cost-effectiveness of individual regulations.

This view goes beyond the issue of accountability to that of Federal regulations in general. For this reason, it sounds much like the industry responses. Like them it emphasizes the idea that individual regulations may be good or at least well intended, while their actual cumulative effect is to restrict the freedom of research severely and to add greatly to its cost.

A view of this problem from the departmental level was provided by Walter Dick, Leader of the Industrial Design and Development Program at Florida State University, Tallahassee.

We have essentially arrived at the point at which only those project centers which can afford, through multiple project funding, to hire a full time business administrator, can survive in a university environment. There are now so many rules and regulations and forms to fill out which are required both by funding agencies as well as the State of Florida and the state university system, that it is almost impossible for an individual researcher to carry out his normal responsibilities and also be able to cope with all the requirements placed on him as a project executive-paper shuffler. . . Several of our faculty members have publicly stated that they will not seek external support because of this situation.

SUMMARY

All of the research sectors reported that they felt a pressure to do short-term, targeted, and applied research rather than long-term and basic research. This pressure was attributed in part to the economic situation, but largely to decisions by the State and Federal Governments. A great many respondents thought that this trend would not only have the effect of damaging the Nation's efforts in basic research, but ultimately would also damage its technological development, and even its position of world leadership.

The remedies that were offered were relatively straightforward and, in broad terms, were the same in all the sectors: fund more basic research, give researchers more freedom in their choice of projects, bring applied and basic research into better balance. The specific suggestions were mostly variations on these themes.

For example, it was stated that NSF has moved away from its commitment to basic research, as is evidenced by its research application programs, and that such programs should be abandoned. Some respondents felt that the public and government should have brought to their attention the difference between basic research, on the one hand, and applied research and development, on the other. Thus they might better understand the special role of basic research, and the need for supporting it. Some respondents, both from universities and industry, suggested that the universities are the best place for basic research, while applied research and development should be the special responsibility of industry. Industry respondents sometimes asked for tax write-off and other dollar incentives that would alleviate the expense of basic research. The reasoning was that such research carries a high risk. It is not guaranteed to benefit the company that performs it, while it may benefit some other company or some other sector. Hence there is reason for the public, through Government funding, to bear some of the cost.

The second great issue is overregulation of research by government. This too was widely reported. With this issue, however, there was more diversity from sector to sector. Thus the problem of government demands for accountability in the use of government-provided research funds was felt especially in universities and Government laboratories. From these sectors came requests for more flexibility in the way funds could be used, and less red tape in the process of applying for funds and accounting for their use. Concern about the constraints imposed by policy-based regulations was universal. There were some suggestions that a broad study should be undertaken to determine the cumulative cost of complying with regulations, particularly at universities. In some instances FFRDC's wished that fewer specific constraints might be imposed on their activities by the Department of Defense.

Industry felt particular concern about Federal regulations. Some statements of this concern reflected the particular product line of an individual company. However, there was a broadly expressed desire to see more favorable patent legislation, tax incentives, or the possibility of relaxing antitrust regulations so as to allow competing companies to pool some of their research efforts. These measures were proposed not only to remedy instances of overregulation, but also to create positive incentives for doing basic research.

CONFIDENCE IN SCIENCE AND TECHNOLOGY

6

CONFIDENCE IN SCIENCE AND TECHNOLOGY 6

The subjects discussed in the three preceding chapters, funding, freedom, and the vitality of the research enterprise, are all internal to the research system itself. The fourth subject is different; it has to do with the way in which persons outside the research system regard that system. As many respondents see it, in recent years both the public and government have lost confidence in research and those who perform it, and therefore are less willing to provide the support they require. In fact, nearly all the problems that the respondents reported, and which the preceding chapters have discussed, were thought to be due, at least in part, to this change in attitude toward science and technology. Therefore, this becomes quite a fundamental concern.

This chapter is divided into two parts. Part I presents the views of the respondents, and is much the same as the preceding chapters. It discusses separately the loss of confidence on the part of the public and on the part of government, as the respondents see it, and attempts to bring out the relation between the two. Some of the explanations that were offered for this change in attitude are also shown, as well as some of its consequences. Another section discusses the remedy most often suggested for this problem, an educational program undertaken by the scientific community in order to communicate better with the public and government and convince them of the value of basic research.

Part II gives a summary presentation of the results of recent opinion surveys concerned with the public's attitudes toward science and technology. The purpose of this is to show what other information is available on the question of whether a recent loss of public confidence has occurred. The complexity of the public's attitudes in this area and the limitations in the available data are also brought out.

PART I.—VIEWS OF THE RESPONDENTS

PUBLIC CONFIDENCE

This problem was perceived in all four sectors. For example, a succinct statement was provided by Stanley J. Lawwill, President of Analytic Services, Inc. (an FFRDC sponsored by the Department of Defense). He emphasizes the importance of public confidence in science and technology to this Nation's position in the world:

> The number one problem which I see facing fundamental (long term, basic) research in the near future is the poor, and deteriorating, National attitude toward science and technology. Until this trend is reversed, I see little prospect for the United States' regaining the dominant position it once held in the discovery of scientific knowledge and in the development and application of technology.

A very similar view was expressed by A. S. Gregory, Director of Central Research and Development at Weyerhaeuser Company. He was especially concerned about the future of American technology:

> The number one problem is society's attitude regarding the importance of scientific and technological advances. . . . Recently, it has become a popular game of the uninformed to state that we have all the science and technology we need and that many of our current problems stem from past technological advances. A significant sector of society does not seem to realize that many of the things that give us our preferred quality of life are possible because of technology.
>
> It is true that we may need to refocus our goals for technology, but I see a need for more technology and not less if we are to meet our challenge of the future.

From Washington State University, President Glenn Terrell wrote of an effect of negative public attitudes on the support of research:

> It occurs to me that perhaps the most significant issue institutional managers and policy determiners face so far as the future of research is concerned is the general attitude that prevails in our nation today about the importance of the research enterprise, itself. Research is expensive; money is in scarcer supply than has been previously the case; there is a surplus of scientists in some disciplines; this gives a combination of factors which has resulted in the development of a general public attitude which is not conducive to overall support for research.

In the past, according to President Terrell, there was a high level of support for graduate education and research, and so researchers became accustomed to general public acceptance of the importance of their work. Now the very legitimacy of the research efforts of our universities is being questioned. University faculty seem to be falling short in their responsibility for pointing out the value to society, not only of applied research, but also of basic research, which is also badly needed for solving society's problems.

Finally S. L. Fawcett, President of Battelle Memorial Institute (an independent research institute) stated the problem in these terms:

> Most basic research is supported with public funds and must therefore be generally recognized as being in the public interest. It is not sufficient that an informed minority should recognize the value of basic research; unless the general public also recognizes that, there will be continuing pressures that will erode the program.
>
> Since the public doesn't really understand how advances in scientific knowledge obtained from basic research lead to improvements in our ability to solve real world problems and thus benefit them, they are apt to believe (from reading about the projects that are brought to their attention through the news media) that basic research is a waste of their money. Unless the true story can be brought to the public in a convincing way, I expect the Nation's basic research program to be eroded.

Consequently, I believe it necessary to find a way to educate the public in such a way that they understand how basic research plays an important role in improving our country's technical, economic, and social well-being.

In comparison with other issues, the public attitude toward science and technology was generally regarded as important by university presidents and vice presidents, as Table E-1 of the Appendix shows. In particular, it ranked third among the presidents and vice presidents (combined) from Carnegie Research Universities II. It also ranked third among department chairmen in the mathematical sciences and fifth in the life sciences.

In industry, low public confidence in science and technology ranked fourth among all respondents, and third among vice presidents and directors of research and development, as can be seen from Table E-2.

In the Government research sector, similarly, meeting public demand for justification of basic research programs with respect to mission was the seventh most frequently mentioned issue. This is shown on Table E-3.

NEED FOR AN EDUCATION PROGRAM

The last writer quoted above recommended a program to convince the public of the value of research. This recommendation, or the parallel recommendation of improved communication between science and government, was made by some respondents from each sector. It was prominently mentioned by respondents from independent research institutes, many of whom saw a need for an adequate justification of research. In the Government laboratories also, many of the respondents tended to view the basic problem as one of communication: scientists have not been effective in communicating, either to Government officials or the general public, a real understanding and appreciation of the value of basic research—or even of the potential of applied research and technology. As one Federal laboratory director stated simply, "A true appreciation for fundamental research in the mind of the non-scientist seems most difficult to achieve." Nevertheless, some respondents, like Robert K. Whitford, Acting Director of the Department of Transportation's Transportation Systems Center and Michael J. Vaccaro, Associate Deputy Director of NASA's Goddard Space Flight Center, exhorted scientists to try to achieve such an appreciation by speaking out.

Whitford felt that:

The central role of R&D in developing scientific understanding of the problems facing our nation and in developing insights concerning probable solutions is poorly understood even within the R&D community itself. Efforts of the R&D community must address the problems of developing the basic understanding and communicating its nature and implications in the context of a sound, scientific societal value system. We must realize and communicate effectively the fact that research itself is a prime means of establishing the human societal value system we all seek. And government must ensure the success of this.

Vaccaro expressed himself this way:

The more important problem is that of achieving a continued public acceptance of the validity of the requirement for fundamental research. A substantial part of this problem lies in the establishment of useful communications channels between the scientific and academic communities on the one hand and the general public on the other.

CONFIDENCE ON THE PART OF GOVERNMENT

In addition to public attitudes toward science and technology, many respondents were especially concerned about attitudes held within government, whether State or Federal. For example, William Montagna, Director of the Oregon Regional Primate Research Center (an independent research institute) felt that basic research, though its products are not marketed in the usual way, does have a price. That price will be paid only if the climate of opinion favors it, and this requires leadership from the Federal Government. If leadership is indifferent to science or against it, or if it misuses science to the detriment of the public, then science becomes ineffective and ultimately the people are impoverished.

The university sector produced many statements of concern about attitudes held within government. This was the fourth-ranked issue among presidents and vice presidents (combined) of Carnegie Research Universities II, and also among all university presidents. Robert MacVicar, President of Oregon State University, mentioned especially the staff members of certain Congressional committees and the Executive Office of the President:

> As a chief executive officer of a university, it would seem to me that the first concern that I would have about the health of short-term fundamental or basic research is a growing antagonism on the part of those in the Federal Government who should be most supportive of it. I speak specifically of the Executive Office of the President and of certain critical Congressional committees, the staff members of which must clearly be aware of the importance of basic research to the long-term well-being of science and indeed the long-term well-being of the United States. Nonetheless, as you are fully aware, both the Executive Office of the President and certain key Congressional committees have been very critical of the National Science Foundation, the National Institutes of Health and other federal funding agencies for their support of certain types of basic research. I do not think that it is enough to chalk this up as some kind of temporary aberration of anti-intellectualism, but rather that it should be confronted for what it appears to me to be; and that is, a very serious breach of confidence between those who must support basic science in the United States and the scientific community.

Alexander Heard, Chancellor of Vanderbilt University, also mentioned State legislatures:

> Anti-intellectual sentiments have been growing in the country, in my view heavily spurred by campus conduct during the time of troubles beginning in 1964. The ramifications are extensive. Recent attacks on National Science Foundation procedures for awarding research grant support are, in my judgment, a manifestation of this skepticism toward intellectuals, universities, and their faculties. Attitudes in state legislatures can lead to actions unsympathetic to fundamental research that are both quicker and surer.

From the University of Cincinnati, Frank R. Tepe, Jr., the Assistant University Dean for Graduate Education and Research, had this to say about a lack of understanding on the part of the public and Congress:

> It is our feeling that the lack of understanding on the part of the American public, and in particular the majority of the members of Congress, of the significance of basic research is the number one problem now facing long-term, basic research. In this age of relevance and immediate return for an investment, the public is not anxious to support the funding of projects whose possible payoff cannot be well documented prior to the initiation of the project. Because of this attitude the funding for basic research and the importance placed on it is decreasing. We would encourage the idea that a program of education, perhaps coordinated by the National Science Foundation or the National Academy of Sciences, be initiated to better educate the public on the long-term benefits and possible far reaching applications of fundamental research.

Thus he also recommends here a program of education directed toward the public.

Finally, A. M. Cormack, Chairman of the Physics Department at Tufts University, found some negative attitudes toward research within the university itself, as well as in the public and government. He also defends the value of basic research:

> There is one problem for the near and distant future which, to my mind, so transcends all others that it is the only one I shall mention. This is the erosion of the traditional view of what the function of a university is. I see this in the

population at large, in many of their elected representatives, in many federal and state bureaucrats (even in the National Science Foundation), and, alas, in many university administrators and students. What I call the traditional view is as follows. A university is a place where scholars congregate to pursue freely the intellectual problems which interest them. In return for this freedom the scholars pass on their knowledge to, and stimulate the intellects of their students.

This view does not imply that professors will pay no attention to the problems of the real world. Some will not, but others will, because many of the problems of the real world are great challenges to the mind. History is replete with examples, from Archimedes on, of people who have made contributions to both the problems of the real world and "ivory tower" problems. History is also replete with examples of an "ivory tower" idea becoming, for better or for worse (and usually it is some of both) of immense concern to mankind at some later time.

Nor does this view imply that teaching will be either highly specialized or sloppy or both. Professors should pay for the freedom to think by teaching well for both the specialist or the generalist.

Many of my colleagues and I feel that the people named in my [first] paragraph have, each in their own way, demanded that we explicitly demonstrate in our work innovations, relevance, concern for interdisciplinary matters and so on to an extent that we have lost much of what is most valuable in solving any problem—time to think.

CAUSES OF DIMINISHED CONFIDENCE

One of the broadest statements of the whole subject of diminished confidence in science and technology came from a social psychologist, Joseph E. McGrath, who is Head of the Department of Psychology at the University of Illinois-Urbana. His letter will be quoted at length. In it, he emphasizes the ways in which he believes the problem arose:

It seems to me incontestable that, during the last 5 to 10 years, there has been a marked erosion in the attitudinal support of basic research—especially research in social science—throughout the nation. This erosion has been reflected in congressional inquiry and comment; in federal executive department modifications of support for research activities; and in comment and critique in the media and in various public forums. Thus the problem has had political, administrative and, above all, attitudinal impact.

To illustrate this, he offers some instances in which he believes members of Congress have attacked specific research programs funded by NSF, or have tried to hamper the peer review process. Other examples he gives are the heavy emphasis in recent years on "immediate" solutions to "relevant" problems, the trend toward massive efforts on single-focus programs, and the increasingly complex and bureaucratized procedures required in the conduct of research with human subjects. He goes on to say:

At a somewhat broader level, I see all of these, and other specific examples, as being manifestations of a strong and growing anti-intellectualism, a major component of which is an anti-science attitude, with an especially strong anti-social-sciences aspect. I see this as a broad public reaction to a great many events of the past 10 years:

a. reactions to the campus unrest in the late 60's and 70's;
b. reactions by people both for and against "affirmative action" efforts of universities on behalf of women and minority group members;
c. reaction to the declining (if not collapsing) job market for persons with college degrees and post-graduate degrees;
d. reactions to the really spectacular gains in prestige (and somewhat in wealth) by the academic community in general during the 1960's. It is also a part of a broader reaction against "establishment" institutions—an anti-elitist and anti-establishment force—in which scientists share with politicians, physicians, attorneys, corporation executives, labor leaders, bureaucrats, and

> even clergymen, in an enormous loss of public confidence. And, we must recognize, it is in part a reaction to unfulfilled "promises"—of all sciences, but perhaps especially of the social sciences.

McGrath further suggests that scientists themselves are to blame for much of this problem, in that the very operation of the research-support and research-publication enterprises has to some degree encouraged scientists to promise benefits that they could not realistically expect to deliver. A scientist is almost forced to make such claims if he is to get research support or even get recognition for his results. But beyond this there seems to be a kind of naivete among many scientists that leads them to believe that their science really can solve any problem, given enough time, money, and effort. He then adds:

> At the same time, while there is a reaction to "promises *not* fulfilled," there is also a reaction to the "threat" of actual accomplishment of some seemingly implied aims. Most notable, in this regard, is the strong negative reaction to use of behavior modification and related techniques ("mind control" and "brainwashing"). In my view, the reactions are far in excess of legitimate concerns. In any case, we are losing confidence *both* for results we have not and cannot deliver, and for results we seemingly can (and might) "deliver."

McGrath's discussion brings out the way in which he felt diminished public confidence has led to detrimental government actions such as the pressure for applied research, and overregulation. He also recommended some possible solutions: For one thing, we can and should train our scientists better with regard to both the logical and ethical limitations of their disciplines. Beyond that, he could only propose "better public education about sciences"—that is, better public relations. But one important part of that might be the development of good high school, junior college, and introductory-level college courses in the sciences.

A similar description of the social origins of this problem came from Dexter P. Cooper, Jr., Vice President of Bell & Howell:

> Atomic fission brought science from the obscurity of the university laboratory into the forefront of American consciousness. With this sudden fame came the feeling that given enough support, technology could conquer all of mankind's problems. The opinions of scientists were widely sought and highly regarded. The period from nineteen-fifty to the mid-sixties saw industry erecting opulent research centers while government funding for basic research seemed an endless cornucopia. The information explosion in scientific journals is dramatic evidence of the impetus that science received in this period.
>
> During the sixties there came an increasing awareness that science not only was failing to solve many of our problems but that the indiscriminate use of technology was contributing to them. The rise of environmentalism has been accompanied by doubts as to the value of science in our society. More and more there was expressed the desire to return to a simpler unpolluted life. The recession of the seventies has added economic pressures to the social malaise and one now hears demands for drastic reduction of government support for research. It may not be too extreme to say that in three decades the scientist has gone from the role of hero to villain in our society.

Thus Cooper contrasts the present with the past, and suggests that the change in public attitude leads to demands for a reduction in government support for research.

Robert G. Sachs, Director of Argonne National Laboratory (an FFRDC), placed diminished confidence in science and technology within the context of a broader change in public attitude:

> All of us are aware of an unfortunate erosion of the intellectual climate in this country, and the attitude toward basic research is just one aspect of this. It seems to me that the next few years will be a critical time to try to restore a climate in which a rational and scientific approach to problems again becomes a way of life.

In some cases, the public's diminished confidence in science was blamed on the influence of the media. For example, Richard A. Greenberg, Vice President, Research and Development of Swift & Company stated that:

> The primary problem is an increasing expression of distrust by the average citizen regarding the true benefits of technological advancement and the motives of the scientific community. This distrust has been vocalized not only by consumer activists who are questioning the entire fabric of American society, but also by scientists who express publicly their fears of potential harmful effects from new technology. The press supplies a ready platform for both factions. As a consequence, the public has been subjected to an almost constant barrage of anti-science verbiage.

Similarly, C. J. Meechan, Vice President, Research and Engineering, of Rockwell International said:

> *There is an apparent decreasing general public confidence in research scientists and an associated poor image of basic research efforts.*
>
> This problem appears at least partially created by the lack of general public understanding of the sophisticated, complex, abstract and seemingly remote scientific issues. It may also be exaggerated by somewhat unbalanced and uninformed reporting of scientific activities by the mass media. If trends continue, it could result in a near complete lack of general public support for basic research and a slipping of the research scientist into a position of irrelevancy. Continued trends in this direction have not only the effect of reducing financial support, but they reduce the prestige of the profession. This may discourage bright, young students from entering a scientific career.

EFFECTS OF DIMINISHED CONFIDENCE

The preceding quotation also suggests that the public's negative attitude may reduce the number of young people entering careers in the sciences. Thus one of the main issues discussed in Chapter 4 can be traced to the present issue of public attitudes. The same position was taken by Harvey B. Willard, Vice Provost and Dean of Science at Case Western Reserve University, who felt that one of the two most important issues facing fundamental research in the near future is:

> the overall climate in this country which has resulted in discouraging a significant number of our very best young people from entering careers in science. . . .
>
> [This] problem is complexly related to the negative attitudes generated by the Viet Nam War and Watergate, to concerns about pollution and environment, and to the state of the nation's economy. Our young people have questioned past practices in most of the established institutions and science has not escaped from their critical eyes. While there are also positive benefits, such as making us all more responsible, the net effect has contributed to the reduction in numbers of our very best young people choosing science as a lifetime career. Other fields also require outstanding people in order to flourish, but it is most unfortunate that more of those with high aptitude for science do not enter the field.

Other university respondents indicated additional problems that they attributed to negative attitudes on the part of the public. George K. Davis, Director of Sponsored Research at the University of Florida, pointed to a pressure to do teaching rather than research, and difficulties related to research support, allocation of personnel, attracting capable young people, and a retreat of some investigators to safer fields:

> It appears to me that a primary problem is the public misunderstanding of the role of fundamental research in our society. Symptoms of this appear in demands of legislators that university staff put more time into teaching and less in research "frills." The so-called Bauman amendment is an evidence of such misunderstanding. There is respect for the accomplishments of science but an attitude that what we need now is rapid transfer of existing knowledge.
>
> This misunderstanding of the role and function of fundamental research pervades many levels of society and, in turn, results in serious roadblocks in terms of support, allocation of personnel,

attraction of capable young people and, because of the ridicule that is often unjustly leveled at investigators carrying on basic research, a retreat of many to "safer" fields of endeavor. One aspect of this has been addressed by Benjamin S. P. Shen (Science Literacy. American Scientist *63:* 265 (1975)) but the issue is far more critical. There is need not only to understand the potential applications of science and technology but a more realistic appreciation of the way in which fundamental research makes its advances and contributions.

Albert Somit, Executive Vice President of the State University of New York at Buffalo, pointed to two more consequences: diminished support for graduate students and instability of funding:

> The misunderstanding of the nature of basic research reflected in the Congressional debate on NSF has the potential of destroying a favorable milieu for scientific and technical research, of extreme value to the nation, which has taken more than a quarter-century to develop. The failure to understand that basic research is fundamentally of indeterminate outcome, and for that reason uniquely capable of providing the information with which unforeseen societal problems will be solved, is especially disturbing. The effect on the NSF budget, and on the relative amount of all Federally supported basic research, is better known to you than me. But the effect on our campus has been to curtail very promising research growth.
>
> There are two areas where this has been particularly felt. First, graduate student support. With the decline of NSF (and other Federally supported) fellowships, it has been necessary to turn to other means of student support. As a consequence, the *number* of supported students has sharply decreased; our resources just will not stretch. We do not know how many able students have decided not to enter the demanding programs in science and technology because they cannot anticipate sufficient support during their studies, but we do know the difficulties under which our students labor when they must support themselves while working toward a degree.
>
> Second, we have encountered increasing difficulty in planning our research programs because of the recent discontinuous nature of NSF support.

Finally, James O. Davis, Chairman of the Department of Physiology at the University of Missouri-Columbia blamed the lack of communication between the scientific community, on the one hand, and the public and government, on the other, for problems like the increased demand for accountability and for applied rather than basic research. He compared the present with a happier situation in the past, in particular with former policies of the National Institutes of Health.

> The first major problem might be classified as one of lack of communication or understanding of the importance of research by people at all levels of endeavor. These include the American public, university administrators and both national and State legislators. This has been evident for several years as we have seen a general shrinkage of available funds from funding agencies such as the National Science Foundation and the National Institutes of Health. There has been an increasing demand by the American public for accountability in the use of funds and this message has been passed on and implemented by our National Congress and the Federal Administration. To a certain extent, this has been a fault of the scientific community in that they have simply failed to take time out of their busy research and teaching programs to inform these various groups. One of the classic examples of the importance of basic research in medicine is illustrated by what happened at the National Institutes of Health from 1949 until 1966 under the leadership of Dr. James Shannon. Over these years which have frequently been referred to as the "Golden Era of American Research" Shannon was able to convince Congress of the importance of basic research and to get an increasing amount of support. Clearly, it was because of this era with almost two decades of intensive research and numerous discoveries that we are now able to use this information and provide much better health care for the American people. Nevertheless, we see that several levels of American society from the American public to Congress and in some cases to the Office of the President lack an understanding of the need and importance of fundamental research, and there are continued

efforts to push applied research which has an immediate practical application.

SUMMARY (Part I)

The main conclusion that can be drawn from the preceding discussion is that there is considerable anxiety in the research community over what they regard as a decline in the public's confidence in science and scientists. This decline is believed to be responsible for certain unfavorable attitudes within government, at both the State and Federal levels. These attitudes in turn lead to actions by government that are detrimental to research. In the eyes of the respondents, this is at least part of the explanation for the many individual problems facing research in the near future.

Some respondents offered reasons for the decline they perceived in public confidence. Very broadly, there seems to have been a growing anti-intellectualism in American society over the last 5 or 10 years. There has also, allegedly, been a loss in public confidence in "establishment" institutions generally. Science has been affected by both of these developments. Some respondents attributed a decline in public confidence to a failure of science to live up to its promises. There is also a feeling that the public perceives science more and more as a positive threat.

There was widespread agreement that the public does not adequately understand science or appreciate its importance. Accordingly, the respondents saw an urgent need for improved communication between the scientific community and the public, and even for a program of education directed to the public.

PART II.—SURVEY DATA ON PUBLIC ATTITUDES

Part I has pointed out the significant and interesting fact that, at this moment in its history, the research community is deeply concerned about a loss of public confidence in science and technology. There is also a widespread feeling that this loss of public confidence is behind many of the specific problems that the research community finds it is having. Since this issue is so important, it would be valuable to see what other information can be obtained on the public's attitudes toward science and technology. As it happens, a certain number of public surveys have been taken on this subject. Part II, therefore, will give a summary of their results.

The National Science Board has already considered this subject to a lesser extent in two previous reports. Both *Science Indicators 1972* and *Science Indicators 1974* contain chapters on "Public Attitudes toward Science and Technology."

In the following discussion, the *Science Indicators* results will be considered first, and will serve as a point of comparison with the other studies. Where possible, use will be made of cumulative papers which attempt to summarize the surveys that have been taken in this area. None of these summaries is entirely complete and up-to-date, and therefore some papers reporting single surveys will have to be discussed also.

Some small-scale or tangentially relevant surveys have been omitted, but the present review does cover all the recent and major studies that were available at the time of writing, and should give an accurate picture of the present state of knowledge. For the sake of brevity, and because the attitudes of the American public are the concern of this chapter, only surveys taken in the United States will be considered.

Since this is a summary, it will not be possible to treat any one study in full detail. A selection will be made to show the kind of questions that have been asked and the distinctions that have been introduced. Emphasis will be placed on those questions that are comparable from one survey to another. There will also be an emphasis on the data that the sources provide rather than on their interpretations and conclusions. For the materials omitted, and especially for important details of methodology, one must of course refer to the original papers.

SCIENCE INDICATORS 1972 AND *1974*

The *Science Indicators* survey was first taken by the Opinion Research Corporation in 1972 and virtually the same survey was repeated in 1974. There was very little difference between the results of the two studies. In one question, the respondents were asked to rate each of nine professions in terms of the "prestige or general standing that each job has". Scientists ranked second, surpassed only by physicians, in both years. Results from another source[1] showed that this had also been the case in 1947 and 1963. Engineers ranked 3.5 in 1972 and 3 in 1974, but only 7 in 1947 and 6 in 1963. The implication seems to be that scientists have maintained a high standing throughout this period, in comparison with most other professionals, while engineers have actually gained in relative prestige.

All the remaining questions had to do with science and technology as such. A sizeable majority (70 percent in 1972 and 75 percent in 1974) believed that science and technology have changed life for the better, while a small

[1] R. W. Hodge, et al, "Occupational Prestige in the United States, 1925-63," *American Journal of Sociology*, Vol. 70, (1964), pp. 282-302.

majority (54 and 57 percent) believed that they have done more good than harm.[2]

The pace of change produced by science and technology was viewed as "about right" by some 50 percent of the public in both years, while approximately 20 percent considered the pace "too fast". About half thought that science and technology will eventually solve some of our problems. In 1972, 30 percent thought that they will solve most of our problems; in 1974, this figure dropped to 23 percent. However, on the whole, these figures seem to show that the public's attitudes toward science and technology are favorable.

Some results were less favorable. For example, although almost half of the respondents felt that the degree of control that society has over science and technology should remain as it is now, 28 percent wished control to be increased. (Only 7 or 8 percent wanted it decreased.) Slightly more than half of the respondents thought that science and technology have caused at least some of our problems. Thus there seems to be some perception of possible dangers from science and technology and therefore of a need to control them.

Of all the good things that science and technology have done, in the minds of the public, "medical advances" by far lead the list. "Improving health care" is also the leading area in which the public would like to see their taxes spent for science and technology. The other leading areas are equally practical. "Discovering new basic knowledge about man and nature" is far down on the list along with "space exploration." This would suggest that the public is not strongly interested in supporting research that is not intended to have practical results.

Attitudes toward science and technology were more favorable among the more highly educated of the population sample and those with higher incomes. The young respondents (18-29 years of age) gave answers similar to those of the total sample. They rated "scientists" significantly higher in prestige than did the total sample, but a somewhat larger percentage of them felt that science and technology have caused some of our problems.

These and the other results of the *Science Indicators* surveys are quite valuable, but they still leave important questions unanswered. For one thing, they consider science and technology together, whereas it would be very interesting to know whether the public regards the two differently. Again, the public's *evaluation* of science and technology needs to be related to its *awareness* and *understanding* of them. An important distinction must also be made between science (or technology) itself and those who practice it. The public may not have the same attitude toward both. *Science Indicators* did not fully explore this distinction. Finally, if one is considering public attitudes, one must ask *which* public. The total public can be divided into many subpublics. In Part I of this chapter some respondents suggested that public attitudes influence attitudes and actions of government. To understand this argument it is important to distinguish various publics that may impinge on government differently. *Science Indicators* made some important demographic breakdowns, but left much more to be done.

For these reasons, the rest of this chapter will explore other studies, both earlier and later than *Science Indicators*. In some cases, these can usefully be compared with the *Science Indicators* data.

FUNKHOUSER

A major effort to synthesize survey data on this subject appeared in a paper "Public Understanding of Science: the Data We Have,"

[2] Although these two questions are quite similar, their numerical responses are different. The reason for this is not clear. However, in both cases the number of those who said that science and technology are predominantly harmful was quite small.

by G. Ray Funkhouser of The Pennsylvania State University.[3]

Funkhouser observes that "In spite of the importance of science and technology at every level of society—from daily living to the philosophical underpinnings of our culture—data on what the public knows, understands and feels about science and technology are embarrassingly scarce."[4] Before enumerating those data, he makes some interesting distinctions between different relevant "publics". He is concerned that spokesmen for science may tend to address themselves to a "public" that they conceive as being much like themselves. From a broad collection of data he argues that the public at large is much less affluent, not nearly as well educated, and somewhat less politically liberal than the academic-professional "concerned citizens" with whom scientists are most at home. It is also far more numerous.

The audiences for the different information media make up a particular type of "public," that is easily subdivided according to the great variety of these media. For example, different magazines have widely different readerships. Workers in the news media constitute a separate public, and what they say in these media, according to Funkhouser, is not necessarily an accurate reflection of the interests and attitudes of the public at large. Legislative bodies and government agencies are extremely important "publics." Though our response letters frequently stated that the actions of government with regard to science spring from attitudes held by the general public, Funkhouser disagrees with that position. He sees many other influences on their actions, such as pressure groups, political supporters, self-interests, and the facts of the matter, which may be more important in a particular case.

Another significant public that he identifies is the "intellectual elite," a self-defined set of people, numbering a few hundred, who dominate the Nation's intellectual journals and are recognized by each other. Few scientists are among them. They are unrepresentative of the public in political orientation and in some other respects. They are likely to have influence with the media and upon political decisionmakers and political activists, according to Funkhouser. He feels that materials primarily aimed at this small group have been construed as "public discussion", while some of their opinions may have been interpreted as evidence of a "public disaffection with science."

Finally, the scientific community is a "public" in its own right. Even here, a distinction must be recognized between academic scientists and engineers and those who work elsewhere.

While these distinctions between different "publics" are important and potentially useful, actual surveys do not use them. Usually they attempt to sample the broad American public, and perhaps analyze that public along demographic lines.

The next subject that Funkhouser discusses is the public's understanding of science. Reviewing material that goes back as far as 1935, he finds that no adequate measurement of general public science knowledge has ever been attempted, but that the few measures that have been taken nationally suggest that the general public does not know many facts about science.

Concerning the public's attitude toward or evaluation of science, Funkhouser reports an extensive study taken by the Survey Research Center (SRC) at the University of Michigan. The questions were asked in 1957 and again in 1958, i.e., shortly before and shortly after Sputnik. In both cases the public appeared to have a rather favorable view of science and also of scientists. (It is notable that no distinction was made between science and technology. Throughout his article, Funkhouser makes little effort to separate the two.) For example, in 1958, 83

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[3] See *Final Report on Workshop on "Goals and Methods of Assessing the Public's Understanding of Science", November 29 and 30, 1972, Palo Alto, California*, by G. Ray Funkhouser, The Pennsylvania State University, Materials Research Laboratory, University Park, Pennsylvania 16802 (January 26, 1973).
[4] Funkhouser, ibid., p. 1.

percent believed that the world is better off because of science. This compares with the *Science Indicators* results presented above (not included in Funkhouser's study) which show that most of the public believed in 1972 and 1974 that science and technology have changed life for the better. While some 40 percent of the respondents felt that scientists are apt to be odd and peculiar people, a majority of 88 percent believed that most scientists want to work on things that will make life better for the average person. Only 26 percent thought that scientists are mainly interested in knowledge for its own sake, regardless of its practical value. Hence, it appears that at that time the public thought of science in practical terms and believed that scientists themselves also thought of it that way. We recall that *Science Indicators* reported that in 1972 and 1974 the public was mainly interested in science for its practical results.

In the late 1960's, at the height of the student protests, West Coast college students were found to have attitudes toward science almost as favorable as scientists had themselves. Beyond this, most data that Funkhouser found had to do with specific, highly visible topics like space exploration, computers, and ecology. From Sputnik to the 1970's, the results would indicate a generally favorable public attitude toward technology. On ecology, the most prominent technological issue, Funkhouser finds that the public has a definite, if superficial and uncommitted, interest in it and virtually no awareness of the scientific and technological issues involved. In summary, his view is that no real effort has been made to assess the public's attitude toward the sciences.

ETZIONI AND NUNN

This is another comprehensive study that covers surveys from the late 1950's to the 1970's.[5] The authors begin with the SRC studies of 1957. At that time most Americans valued science highly, mainly because they saw it as instrumental in achieving goals they valued. About one person in ten thought that some scientific developments, such as armaments, were undesirable. Only one person in ten saw science as helpful or interesting, and even fewer saw it as "exciting." (By contrast, *Science Indicators* found 23 percent in 1972 and 22 percent in 1974 expressing "excitement or wonder" as their general reaction to science and technology.)

A later study discussed by Etzioni and Nunn compared the SRC results with data collected in 1964 by the National Opinion Research Center (NORC). The proportion of people who thought that science breaks down people's ideas of right and wrong increased from 23 percent in 1957 all the way to 42 percent in 1964. Similarly, the proportion who agreed that science makes our way of life change too fast went up from 43 percent in 1957 to 57 percent in 1964. The authors do not mention a repetition of essentially the same question by NORC in 1968, in which 54 percent answered in the affirmative.[6] From these results it would appear that there was an increase in the public's sense of threat from science from 1957 to 1964, and that this feeling remained about the same from 1964 to 1968. The middle 60's, of course, are the time when some of our letter respondents suggested that the public began to react against science.

The foregoing data have to do with the public's attitude toward science (but without distinguishing science from technology). For further light, Etzioni and Nunn turn to survey data on the public's attitudes toward scientists, in the hope that attitudes toward the practitioners of science may serve as an indirect measure of attitudes toward science itself. In 1957 and 1958, SRC reported a positive public

[5] Amitai Etzioni and Clyde Nunn, "The Public Appreciation of Science in Contemporary America," *Daedalus*, (Summer 1974), pp. 191-205.

[6] NORC Study SRS-4050 (April 1969), Question 61. As was noted earlier, *Science Indicators* asked much the same question in 1972 and 1974. Unfortunately, their method allowed for three possible answers instead of two, so that the results cannot be compared with those reported here.

attitude toward both science and scientists, as was already noted. Since 1966, either Louis Harris or NORC has periodically asked the question, "Would you say that you have a great deal, only some, or hardly any confidence in those people running the scientific community?" This question, the authors note, may tap feelings about authority as well as about scientists as such.

In 1966 those expressing a "great deal" of confidence were 56 percent of the total sample; in 1971, 1972, and 1973, they were 32, 37, and 37 percent. (In 1974 and 1975, the figures were 45 and 38 percent.)[7] These figures do suggest some drop in public confidence in scientists from 1966 to 1971, which has essentially persisted up to 1975. On the other hand, those expressing "hardly any confidence" were never more than 10 percent of the total. This would suggest that at least scientists have not drawn any great amount of positive mistrust.

However, Etzioni and Nunn go on to compare the percentage who expressed a great deal of confidence in scientists with the percentage for other professions. They find that in 1966 and 1971 science ranked fifth, surpassed by the military and education, as well as by medicine and finance. In 1972 it was third, behind medicine and finance. But in 1973 only medicine ranked higher.[8] (In 1974 the leaders of the scientific community ranked third; in 1975 they ranked second.)[9] The implication is clear: Though there may have been a decline in prestige by science leaders in absolute terms, this decline was shared by the other leaders to an even greater extent. Hence, in comparison with other professionals, scientific leaders actually gained in this period, according to this survey.

In support of this conclusion, we may note the *Science Indicators* results, which were alluded to above. In 1947, 1963, 1972, and 1974 the profession of scientist consistently ranked second in prestige. (Medicine again was first.) This is not exactly the same as the result just discussed, perhaps because the question asked was rather different. But still it seems clear that there has been no loss of prestige by scientists in comparison with other professionals and therefore, presumably, no relative decline in public confidence.

The data collected by Etzioni and Nunn which have been seen thus far seem to imply that the public's sense of a threat from science (and technology) has increased, especially from 1957 to 1964, while the prestige of scientists as a professional group has gone down, especially from 1966 to 1971. In this sense, those respondents to the letter inquiry who were concerned about a public loss of confidence in science may have been correct. However, all available results seem to indicate that scientists have not lost prestige *in comparison with other professionals*, and, between 1966 and 1975, may even have gained.

Etzioni and Nunn mention another significant, though complicating, factor. Compared to all other institutions in 1973, science received the *highest* percentage of "don't knows" when the question of confidence was asked. This was also the case in 1974 and 1975.[10] (This is consistent with Funkhouser's conclusion that the public is not well informed about science.) Thus, the critical reader might wonder whether the high prestige that the public accords to scientists is based on any depth of understanding. It is conceivable that the public judges occupational prestige in a very superficial way.

Like *Science Indicators*, Etzioni and Nunn now analyze "the public" in terms of demographic categories. Secondary analysis of the 1973 NORC data shows that people from 18 to 29 years old, those often believed to harbor strong anti-science sentiment, have more con-

[7] NORC General Social Survey, National Data Program for the Social Sciences, 1974 (Question 87) and 1975 (Question 77).
[8] Here they have made a slight error. Education also ranked marginally higher in 1973.
[9] NORC, ibid.

[10] NORC, ibid.

fidence in those who run science than any other age group. (However, the data suggest that education is more important than age as a predictor of confidence in scientists.) According to Harris Poll data, gathered from a national sample of college students in the spring of 1965, the scientific community was accorded more confidence than any other institution. In a national survey of youth in 1968, Yankelovich found that 88 percent of college students agreed that "the problem is not technology—it's what society does with technology." Those with low incomes or with low occupational prestige ratings were found to have relatively low confidence in scientific leaders. These results are highly consistent with both *Science Indicators* and Funkhouser.

Finally, the authors point to complexities and inconsistencies in attitudes toward science and technology, even within the same individual. Many people approve of science for its usefulness, but a much smaller number understand or appreciate it as a search for knowledge. In both groups, a significant minority feel highly threatened by science.[11] In the case of technology, it is not unusual to find the same person expressing both pro- and anti-technology sentiments. These considerations suggest that much more information is needed in this area, and much care must be taken not to oversimplify when interpreting public attitudes.

THE CALIFORNIA POLL

In connection with the public's ranking of various professions, mention should also be made of the California Poll, based on the population of that State, which found that "research scientists" were the only group in which more than one-half of the public expressed a "lot of confidence" in both 1973 and 1975.[12] In this case, scientists even ranked ahead of physicians. On the other hand, in almost every case in which a statistically significant change occurred between 1973 and 1975 in the way the public regards a particular institution, that institution suffered a loss of public confidence. Thus one finds here the same loss of confidence in institutions in general that was recorded by Louis Harris and NORC. At the same time, scientists did very well in relative terms.

AHLGREN AND WALBERG

High school students are entitled to be considered a "public" in their own right. As was stated in Chapter 4, many respondents to our letter inquiry were concerned that these people are losing interest in science, so that they will not wish to enter this field and thereby keep up the supply of research personnel. It is interesting, therefore, to look at the studies that have been performed recently on the attitudes of adolescents. One such study was reported by Alhgren and Walberg.[13]

Besides presenting their own work, these authors briefly review the preceding studies in this area, beginning with the classic study by Mead and Metraux in 1957.[14] There it was found that the scientist was perceived as being essential to our national life for the wonders he can produce. On the other hand, though he is brilliant, he is indifferent both to the world outside his laboratory and to any personal relationships. His work is dull and monotonous, and so is he. Ahlgren and Walberg, in their own survey, asked 96 high school physics students

[11] This is based on a secondary analysis of the 1957 SRC data.

[12] The California Poll, Field Research Corporation, Release #858, Thursday, May 29, 1975.

"Data for this study, originally collected by the Field Research Corporation, were provided by the University of California State Data Program, Berkeley. These organizations are not responsible for the analysis and interpretation of data appearing here."

[13] Andrew Ahlgren and Herbert J. Walberg, "Changing Attitudes towards Science among Adolescents," *Nature*, Vol. 245, (September 28, 1973), pp. 187-190.

[14] Margaret Mead and Rhoda Metraux, "Image of the Scientist among High-School Students: A Pilot Study", *Science*, Vol. 126, No. 3270 (August 30, 1957), pp. 384-390.

to rate each of eight different occupations. Their image of the physicist was the most remote from their image of themselves. He was perceived as being very "important" and "mature", but very "unfriendly".[15] The biologist was perceived as being about midway between the physicist and the student himself, more "friendly" but less "important" and "mature". Data taken on 1,011 students showed that high interest in physics correlated most strongly with the perception of it as beneficial or important, and least strongly with the perception of its being mathematical or technical. There was a negative correlation between such interest and the perceived difficulty of physics.

PURDUE OPINION POLL

This is a 1975 survey of 2,000 high school students throughout the Nation.[16] Many questions were asked in order to determine the attitudes and other characteristics of students who choose careers in the sciences, in comparison with other students. With regard to attitudes toward science and technology, 75 percent of all students felt that "the by-products of past scientific efforts have been, on the whole, beneficial to man;" 71 percent felt that "overall, science and technology do more good than harm." On the other hand, 69 percent of the respondents agreed that "money should not be given for scientific research unless it has practical value." (In a similar poll taken in 1957, only 26 percent agreed with this position.) Most respondents favored spending tax money for cancer research, improving the environment, food production, and searching for alternative sources of energy, but not for space research.

The results of the last two studies would suggest that high school students do have a negative image of scientists, but that it is nothing new; they had the same image in 1957. In their evaluations of science and technology as such, high school students seem to be quite close to the rest of the American population. In neither case does the evidence suggest that these people have recently and dramatically turned against science.

TAVISS

A few researchers have emphasized the distinction between science and technology, and have tried to ascertain the attitudes of the public toward technology as such. One such study (briefly mentioned by Etzioni and Nunn) reports on a small sample from the Boston area, surveyed in 1970.[17] Strong majorities believed that "machines have made life easier" and that "computers make business and government more efficient." On the other hand, majorities almost as great felt that "people today have become too dependent upon machines," and that "the quality of life is better in the country than it is in the city." Thus there seems to be a high degree of ambivalence.

The author notes that it is difficult to interpret results of this kind in the absence of more detailed information. Respondents have a tendency to respond "yes" to all questions, and there is also the difficulty of knowing how deeply these attitudes are held. They may be only vague "philosophical" commitments, or they may actually be beliefs that would affect behavior and other attitudes. The author suspects that the former is the case.

Whatever its significance, Taviss notes that this ambivalence toward technology has increased since the 1957 SRC study. Still, over three-fourths of the sample queried agreed that

[15] These terms are composites of an original fifteen semantic-differential scales.

[16] *Factors Influencing the Career Plans of High School Students*, by Arline C. Erlick and William K. Le Bold, Report of Poll 101 of The Purdue Opinion Panel, June 1975, Measurement and Research Center, Purdue University, West Lafayette, Indiana 47907. This publication was prepared pursuant to a grant from the National Science Foundation.

[17] Irene Taviss, "A Survey of Popular Attitudes toward Technology", *Technology and Culture*, Vol. 13, No. 4 (Oct. 1972), pp. 606ff.

technology does more good than harm, and 83 percent felt that overall, technology is more beneficial than harmful. (This is consistent with *Science Indicators* and other results discussed above.)[18] By far the main impact of technology was said to be in the area of improved medical care. (This also is consistent with the other results discussed earlier.)

The respondents were asked to rank-order the technological and social programs they would like to see implemented. The results were quite similar to *Science Indicators*, given that the items compared were not exactly the same. It was found that individuals who were more educated or better informed on technological issues were more likely to be pro-technology.

The survey also sought to determine whether the process of decisionmaking is approved. Does the public feel that the "experts" play too large a role in government decisionmaking? This would presumably reflect their attitudes toward both scientists and technologists. On most issues, such as fluoridation, installing missiles, and funding for scientific research, the sample surveyed would like experts to have more power. Only on the issue of sending men to Mars was there a wish to see experts have less power. Taviss distinguishes between a pro-technology group that seems to represent the "mainstream culture" and an anti-technology group that shows signs of being "alienated".

EBASCO SERVICES

In the same connection, a 1975 study should be mentioned, which had to do with public attitudes toward the development of nuclear energy.[19] Scientists were the group that enjoyed the greatest confidence with regard to what they had to say on this issue. This was true for respondents representing the total public, political leaders, business leaders, and regulators. It was not true for environmentalists, who placed scientists second, after "leading environmentalists."

LA PORTE AND METLAY

This is a very extensive study of public attitudes toward technology, which was published quite recently.[20] Only some highlights can be presented here. The study is based on a survey taken of the California population in 1972 and again in 1974. The authors note some of the general difficulties with this kind of inquiry: The data gathered are based on "opinions" which may be transiently held, particularly where they relate to concerns not highly central to the person being questioned (a point also made by Taviss). Opinions may be based on misinformation, and therefore may be altered when new facts become known. There are measurement problems as well. However, the authors find considerable consistency in the answers of individual respondents over time, and believe that confidence in the results is warranted.

Like previous authors, La Porte and Metlay analyze the surveyed population in demographic terms. In addition, they distinguish what they call the "potential public for technological politics", which they compare with the broad public. The "potential public" is the highly educated and politically active portion of the population; they are thought to be the ones most likely to make articulate demands

[18] As noted, there is some ambiguity in *Science Indicators* on this question.

[19] *A Survey of Public and Leadership Attitudes toward Nuclear Power Development in the United States*, conducted for Ebasco Services Inc. by Louis Harris and Associates, Inc. (August 1975), p. 105.

[20] *They Watch and Wonder: Public Attitudes toward Advanced Technology*, by Todd La Porte and Daniel Metlay, Institute of Governmental Studies, University of California, Berkeley, December 1975. Final Report to Ames Research Center, National Aeronautics and Space Administration (NASA Grant NGR 05-003-0471).

Preliminary reports of this study appeared as "Technology Observed: Attitudes of a Wary Public," *Science*, Vol. 188 (April 11, 1975), pp. 121-127, and "Public Attitudes Toward Present and Future Technologies: Satisfactions and Apprehensions", *Social Studies of Science*, Vol. 5 (1975), pp. 373-398.

for change and to exert political pressure on behalf of their convictions. (Therefore they are the kind of group that some of our letter respondents would like to reach with an educational program.)

The first major conclusion that the authors draw is that the public perceives a distinction between the activities of "science" and those of "technology". (In this they differ from Etzioni and Nunn.) Majorities disagreed with the proposition that controls on technology will make life worse; with some ambiguities, there was agreement that we ought to increase our controls over the way technologies are used. By contrast, there was a very strong consensus that *scientific* activities are intrinsically beneficial and should not be controlled. There was considerable confidence in scientific thinking as a means for solving social problems, and strong disagreement with the proposition that thinking in a scientific manner precludes one's appreciation of "most of life's beauties." Favorable attitudes toward science correlated most strongly with higher levels of education.

Regarding the *outcomes* of technology, the urge to go back to nature and the belief that technology makes life too complicated were held by only about one-third of the total population. The notion that technology leads to a debilitating materialism was subscribed to by only a quarter of the sample, but two-thirds agreed with the less extreme statement that we have become too dependent on machines. An overwhelming majority rejected the statement that "People shouldn't worry about harmful effects of technology because new inventions will always come along to solve the problems." Negative attitudes toward the outcomes of technology were more common among the young, the politically liberal, and the poor.

With regard to the outcomes of *science*, there was strong agreement that scientific discoveries are good and only their use is problematical. On the other hand, the samples were nearly evenly divided as to whether or not scientists, if left alone, can be counted on to discover things that will make our lives better.

In general, the authors find important distinctions in the public mind between the intrinsic values of science and technology, the need to control one or the other, and their separate outcomes. If one compares these data with *Science Indicators*, the results are generally the same, except for the fact that *Science Indicators* did not distinguish between science and technology. That study found that the public was mainly in favor of science and technology, but many still wished them to be more closely controlled. The La Porte and Metlay study was able to refine these conclusions. On the other hand, *Science Indicators* found that the public has little interest in the pursuit of knowledge for its own sake. According to La Porte and Metlay, the public believes that scientific discoveries in themselves are good.

The respondents were also asked whether additional uses of technology would improve, aggravate, or have no effect on solving each of ten social problems. Solid majorities saw technology aiding in mass rapid transit, solving the energy crisis, protecting the environment, curbing population growth, and education. But almost a quarter thought technology would aggravate the problems of unemployment and the cost of living, and there was a strong dissent from the use of technology in connection with the maintaining of personal records. In general, the respondents perceived most (but not all) past and presently implemented technologies as beneficial, and technology as useful in the solution of some (but not all) social problems. These results should be compared with the *Science Indicators* questions noted above as to whether science and technology have caused many of our problems, and whether they will solve them.

A query similar to Taviss' was made as to which of eight actors participating in decision-making about technology *actually* has the most and which the least say. They were also asked who *ought* to have the most say. In none of the policy areas were the individual and/or the public-at-large believed to exert any significant influence over decisions, while at the same time the public was thought to be the group most entitled to have such influence. Technical experts rated quite highly; they were seen as legitimately exercising a great deal of influence in every area. There was considerably less support for Executive Branch leaders in the Government, and for business leaders. These results can be compared with the consistently high standings that scientists (and engineers) hold in the public's esteem, in comparison with other professionals, in the studies previously discussed.

Questions were also asked about the impact that the respondents anticipated from a list of future technologies. Mainly beneficial results were expected from most of the technologies listed: particularly, urban rail transit and solar energy. The only predominantly negative responses were to genetic engineering and massive data banks of information about the public, but there was also relatively little support for the anti-ballistic missile, the SST, and space travel. The public proved to have quite different reactions to different technologies. Previous studies have also inquired about public reaction to different technologies, but it is difficult to make a quantitative comparison because of the different technologies considered and the different questions asked.

In general, hopes for benefits from future technology were most often expressed in terms of the directly intended consequence of that technology—some improvement in instrumental technique. Fears about harms, on the other hand, were most often expressed in terms of unintended, indirect consequences for social or political values such as the economy, the environment, or political rights. General anxiety toward *all* technologies appeared to decrease from 1972 to 1974, as a more focused concern about the negative aspects of *particular* technologies emerged. This qualified confidence was paralleled by an increase in confidence in scientific activities. The single instance of significantly increased support for a technology was the enhanced attractiveness to the "potential public" of developments in the space program. The authors find this development to be due largely to an increase of interest in the scientific information that this program can produce. Demographic analyses showed that a certain group might very well value one technology and fear another.

SUMMARY (Part II)

The survey data that have been described in Part II are clearly very incomplete. For example, much more needs to be done to survey the attitudes of different groups within the broad public. Some studies have attempted to separate attitudes toward science and toward technology, to distinguish between different technologies, and to distinguish attitudes toward fields from attitudes toward those who work in them. This work should be extended and continued over time, so that changes in attitude can be followed. Moreover, some studies contain the explicit suggestion that they may be reporting only superficial and uninformed opinions that may easily change, and may not express any serious convictions or intentions. This too is an area for further work, especially with regard to the depth of understanding of science and the motivations that underlie public attitudes. Finally, the results of separate studies have been compared without critically probing the question of the consistency between them or the validity of individual surveys.

Because of these limitations in the data only tentative conclusions can be offered. Perhaps the clearest conclusion is that there has been a general drop in the public's esteem for public institutions generally since the middle 1960's. In absolute terms, scientists have shared in this drop, but in comparison with other professionals they have held their own or even gained. The public also has a high degree of respect for scientists as experts entitled to take part in public policy decisions. It must be added that on the whole scientists are perceived to be rather strange people with whom the public does not easily identify.

Some of our letter respondents proposed a program of education about science and scientists directed toward the public. There is evidence that the public could know much more about these subjects. However, without further study it cannot be asserted that such a program would lead to the alterations in governmental actions with respect to science that these respondents hoped for.

Science itself seems to be highly regarded by the public. Most of the evidence suggests that it is valued mainly for its practical results, but this point is still unclear. At the same time, there is some evidence that the public distinguishes science from technology. Technology also is widely supported, but public concern about it is increasing. Different technologies seem to receive widely different reactions from different constituencies. Young people seem to be especially sensitive to the possible negative consequences of technology, but it does not appear that they have become generally disaffected with either science or technology.

APPENDICES

Appendix A
METHOD OF THE INQUIRY

The purpose of this appendix is to add further details to the description in Chapter 2 of the procedure of sending inquiry letters to the research community and processing the replies.

The inquiry letters were mailed out in the spring and summer of 1975, on the dates shown in Table A-1. In particular, on July 1 letters were sent to vice presidents for research at universities, asking for the names of five of their department chairmen. At that time, each vice president also received five copies of the inquiry letter to distribute to those chairmen. Hence those letters were received by the chairmen on or after July 1. Appendix B contains the texts of all the letters sent.

Each individual who received an inquiry letter and did not send a reply was contacted with a follow-up telephone call, if he or his organization could still be located. These calls occurred in August and September.

The processing of the response letters was terminated on September 22. Letters received after that date could not be included in the tabulation of issues, though they are counted in Chapter 2 and in the complete list of respondents in Appendix C. About 15 letters were thereby excluded, all from department chairmen at universities.

In December and January, a new letter was sent to some of the persons who had responded to the inquiry letter. This new letter sought their permission to use a quotation from their response in the present Report. The exact passage to be quoted was included, so that they could agree that the passage accurately represented their views. Thus written permission has been obtained for the use of every attributed quotation from a respondent that appears in this Report.

At universities, the officials who had been contacted were divided into three levels, which for working purposes were called presidents, vice presidents for research, and department chairmen. This was a simplification of the actual situation. For one thing, the Carnegie Commission listings sometimes name individual campuses of multicampus institutions, while at other times they list the whole institution as a single unit. The "president", therefore, is whatever official is highest in the unit listed, whether the whole institution or a single campus. Some of these officials are in fact chancellors. Vice presidents for research were selected in the same way if an official could be found with that title or a similar one. If not, an official was chosen whose responsibility seemed to be in much the same area, such as the dean of graduate studies. In a few cases a vice president for research was contacted from a central university administration, rather than from an individual campus that happened not to have such an official.

The department chairmen were from whatever campus the vice president for research happened to choose. In almost every case, these were the campuses in the Carnegie Commission list. These persons had various titles. Some were heads of university-based research laboratories. Others were actually deans or assistant deans of academic divisions, but were still counted as chairmen. In other cases, the respondent was a member of the department other than the chairman.

In a number of cases, a person addressed by our inquiry letter delegated to someone else the responsibility of replying. Whenever it could be ascertained that this had occurred, the reply was counted as coming from the person originally addressed, regardless of who had actually written or signed it.

Occasionally the author of such a reply was also writing on his own behalf because the inquiry letter had also been sent to him. In this case, the letter was counted twice, as the response of both officials.

The inquiry letter asked each respondent to propose the two most critical issues or problems facing research along with any solutions he cared to suggest. When the letters were analyzed, the difference between a problem and a solution often proved to be very slight. A problem such as lack of money in some area implies its own solution directly, while some proposed problems, such as the lack of long-range planning, are solutions more than problems.

The classification of responses was difficult for many reasons. A set of categories had to be developed that was not so fine-grained as to fail to classify, by leaving a great number of distinct categories. Yet it could not be so coarse as to lose entirely the many differences of nuance among the letters. Again, the degree of coarseness ideally should be the same for all categories. It was also found that the issues as specified by our set of categories were closely interconnected in the minds of the respondents. Thus what they called an "issue" or "problem" might in fact bring up several categories, especially if it was in a long statement. Because of these difficulties, which are to be expected in a content analysis, it did not seem appropriate to present the survey results in the form of frequency tables. In place of this, rank-order tables were developed, as shown in Appendix E, which are not as quantitatively detailed. This kind of semiquantitative tabulation is suitable to the non-statistical character of this inquiry, the purpose of which is not to report quantitatively on the relative importance of issues, but simply to identify the most important ones. Appendix D contains a complete list of the categories or issues from each sector.

Table A-1.—Mailing Dates

Universities	
Presidents	First two weeks of June 1975
Vice-Presidents	
First Letter	May 21, 1975
Second Letter	July 1, 1975
Department Chairmen	On or after July 1, 1975
Industry	
NSF Industrial Panel	May 23, 1975
Presidents of Corporations	May 23, 1975
Government	
Directors of FFRDC's	July 11, 1975
Directors of Intramural Laboratories	June 2, 1975
Agency Officials	May 30, 1975
Independent Research Institutes	
Presidents or Directors	May 23, 1975

Appendix B
TEXTS OF THE LETTERS SENT TO THE RESEARCH COMMUNITY

The following are copies of the letters sent to the research community by the Chairman of the National Science Board Committee that was responsible for this Report. These inquiry letters varied slightly according to the sector and the title of the person addressed. All the versions of the letter are included here.

In addition, the second letter to university vice presidents for research is included. This is the letter that asked each vice president to designate five department chairmen and distribute copies of the inquiry letter to them.

NATIONAL SCIENCE FOUNDATION

NATIONAL SCIENCE BOARD

WASHINGTON, D.C. 20550

LETTER TO
UNIVERSITY PRESIDENTS

Currently the National Science Board is preparing its Eighth Annual Report to the President and to the Congress. The report will concentrate on the circumstances which might affect the capacity of the Nation to continue a strong position in science and technology. It will attempt to identify and to study prospectively selected critical problems developing in the operating research sectors---namely, university, industry, Government laboratories and independent research institutes. The report is not as much concerned with dollar support as with circumstances in the institutional, managerial or policy environment which will influence the productivity of working scientists and engineers. In order to identify critical problems arising from university research activities, the Committee on Eighth NSB Report is seeking input from selected university presidents who can speak to such issues on a university-wide basis.

The Committee would very much appreciate learning about the two most critical issues/problems facing fundamental (long term, basic) research, as you see it, in the near term future. "Near term future" means issues currently emerging or seen-to-be-emerging in the next decade or so. For example, as you look ahead, in your capacity as what problems do you anticipate? What critical issues/problems will condition scientific and technological research in your university and will decrease its effectiveness unless properly addressed? Would you please order your issues/problems "one" and "two" and then provide a brief descriptive paragraph or so for each? Feel free to propose resolutions or solutions.

In addition to your views from the chief executive level, the Committee expects to obtain perceptions from your chief administrative officer for research in a separate letter.

In the name of the National Science Board and its Committee for the Eighth NSB Report, I thank you for a quick reply. If at all possible, we would very much appreciate having your comments within the next few weeks or so. An addressed, franked envelope is enclosed.

Many thanks for your time, interest and effort.

Very truly yours,

F. P. Thieme, Chairman
Committee on Eighth NSB Report

Enclosure

NATIONAL SCIENCE FOUNDATION

NATIONAL SCIENCE BOARD

WASHINGTON, D.C. 20550

FIRST LETTER TO UNIVERSITY VICE-PRESIDENTS FOR RESEARCH

Currently the National Science Board is preparing its Eighth Annual Report to the President and to the Congress. The report will concentrate on the circumstances which might affect the capacity of the Nation to continue a strong position in science and technology. It will attempt to identify and to study prospectively selected critical problems developing in the operating research sectors---namely university, industry, Government laboratories and independent research institutes. The report is not as much concerned with dollar support as with circumstances in the institutional, managerial or policy environment which will influence the productivity of working scientists and engineers. In order to identify critical problems for the university research sector, the Committee on Eighth NSB Report is seeking input from selected individuals with direct concern for research in U. S. academic institutions.

The Committee would very much appreciate learning about the two most critical issues/problems facing fundamental (long term, basic) research, as you see it, in the near term future. "Near term future" means issues currently emerging or seen-to-be-emerging in the next decade or so. For example, as you look ahead, in your capacity as what problems do you anticipate? What critical issues/problems will condition scientific and technological research in the university and will decrease its effectiveness unless properly addressed? Would you please order your issues/problems "one" and "two" and then provide a brief descriptive paragraph or so for each? Feel free to propose resolutions or solutions.

In addition to your views, the Committee expects to obtain the view of the President of your university in a separate letter.

On behalf of the National Science Board and its Committee on Eighth NSB Report, I thank you for a quick reply. If at all possible, we would very much appreciate having your comments within the next few weeks or so. An addressed, franked envelope is enclosed.

Many thanks for your time, interest and effort.

Very truly yours,

F. P. Thieme, Chairman
Committee on Eighth NSB Report

Enclosure

NATIONAL SCIENCE FOUNDATION
NATIONAL SCIENCE BOARD
WASHINGTON, D.C. 20550

SECOND LETTER TO UNIVERSITY VICE-PRESIDENTS FOR RESEARCH

Earlier I wrote to you concerning the top two critical problems/issues facing the conduct of research in University in the near-term future. As responses come in to us, we sense the need for additional input from the departmental level and would like to ask your help in obtaining a set of critical issues from five chairmen of your most active departments in science (including social science) and engineering. I shall depend on your selection to ensure a spread among disciplines as well as a fairly quick reply.

Would you please provide the names of the chairmen you select on the enclosed card addressed to me and then give each chairman a copy of my enclosed letter.

Very truly yours,

F. P. Thieme, Chairman
Committee on Eighth NSB Report

Enclosures

NATIONAL SCIENCE FOUNDATION
NATIONAL SCIENCE BOARD
WASHINGTON, D.C. 20550

LETTER TO UNIVERSITY DEPARTMENTAL CHAIRMEN

Dear Departmental Chairman:

Currently the National Science Board is preparing its Eighth Annual Report to the President and to the Congress. The report will concentrate on the circumstances which might affect the capacity of the Nation to continue a strong position in science and technology. It will attempt to identify and to study prospectively selected critical problems developing in the operating research sectors--namely university, industry, Government laboratories, and independent research institutes. The report is not as much concerned with dollar support as with circumstances in the institutional, managerial or policy environment which will influence the productivity of working scientists and engineers. In order to identify critical problems for the university research sector, the Committee on Eighth NSB Report is seeking input from selected departmental chairmen in U. S. academic institutions.

The Committee would very much appreciate learning about the two most critical issues/problems facing fundamental (long term, basic) research, as you see it, in the near term future. "Near term future" means issues currently emerging or seen-to-be-emerging in the next decade or so. For example, as you look ahead, in your capacity as departmental chairman, what problems do you anticipate? What critical issues/problems will condition scientific and technological research in the university and will decrease its effectiveness unless properly addressed? Would you please order your issues/problems "one" and "two" and then provide a brief descriptive paragraph or so for each? Feel free to propose resolutions or solutions.

On behalf of the National Science Board and its Committee on Eighth NSB Report, I thank you for a quick reply. If at all possible, we would very much appreciate having your comments within the next few weeks or so. An addressed, franked envelope is enclosed.

Many thanks for your time, interest and effort.

Very truly yours,

F. P. Thieme, Chairman
Committee on Eighth NSB Report

Enclosures

NATIONAL SCIENCE FOUNDATION

NATIONAL SCIENCE BOARD

WASHINGTON, D.C. 20550

LETTER TO MEMBERS OF NSF INDUSTRIAL PANEL

Currently the National Science Board is preparing its Eighth Annual Report to the President and to the Congress. The report will concentrate on the circumstances which might affect the capacity of the Nation to continue a strong position in science and technology. It will attempt to identify and to study prospectively selected critical problems developing in the operating research sectors---namely, university, industry, Government laboratories and independent research institutes. The report is not as much concerned with dollar support as with circumstances in the institutional, managerial or policy environment which will influence the productivity of working scientists and engineers. In order to identify critical problems for the industrial research sector, the Committee on Eighth NSB Report is seeking input from members of NSF Industrial Panel on Science and Technology.

The Committee would very much appreciate learning about the two most critical issues/problems facing fundamental (long term, basic) research, as you see it, in the near term future. "Near term future" means issues currently emerging or seen-to-be-emerging in the next decade or so. For example, as you look ahead, in your capacity as a research director, what problems do you anticipate? What critical issues/problems will condition scientific and technological research in industry and will decrease its effectiveness unless properly addressed? Would you please order your issues/problems "one" and "two" and then provide a brief descriptive paragraph for each? Feel free to propose resolutions or solutions.

In addition to your views from the research management level, the Committee expects to obtain perceptions from the corporate executive officer in a separate letter.

In the name of the National Science Board and its Committee on Eighth NSB Report, I thank you for a quick reply. If at all possible, we would very much appreciate having your comments within the next few weeks or so.

Many thanks for your time, interest, and effort. If you have any questions regarding this letter please contact Dr. James J. Zwolenik at 202-632-5786.

Very truly yours,

F. P. Thieme
Chairman, Committee on
Eighth NSB Report

Enclosure

NATIONAL SCIENCE FOUNDATION

NATIONAL SCIENCE BOARD

WASHINGTON, D.C. 20550

LETTER TO CORPORATION PRESIDENTS

Currently the National Science Board is preparing its Eighth Annual Report to the President and to the Congress. The report will concentrate on the circumstances which might affect the capacity of the Nation to continue a strong position in science and technology. It will attempt to identify and to study prospectively selected critical problems developing in the operating research sectors---namely, university, industry, Government laboratories and independent research institutes. The report is not as much concerned with dollar support as with circumstances in the institutional, managerial or policy environment which will influence the productivity of working scientists and engineers. In order to identify critical problems for the industrial research sector, the Committee on Eighth NSB Report is seeking input from selected corporate officers in U. S. industry.

The Committee would very much appreciate learning about the two most critical issues/problems facing fundamental (long term, basic) research, as you see it, in the near term future. "Near term future" means issues currently emerging or seen-to-be-emerging in the next decade or so. For example, as you look ahead, in your capacity as a company president, what problems do you anticipate? What critical issues/problems will condition scientific and technological research in industry and will decrease its effectiveness unless properly addressed? Would you please order your issues/problems "one" and "two" and then provide a brief descriptive paragraph for each? Feel free to propose resolutions or solutions.

In addition to your views from the corporate level, the Committee expects to obtain perceptions from the operating research level in a separate letter.

In the name of the National Science Board and its Committee on Eighth NSB Report, I thank you for a quick reply. If at all possible, we would very much appreciate having your comments within the next few weeks or so.

Many thanks for your time, interest, and effort. If you have any questions regarding this letter, please contact Dr. James J. Zwolenik at 202-632-5786.

Very truly yours,

F. P. Thieme
Chairman, Committee on
Eighth NSB Report

Enclosure

NATIONAL SCIENCE FOUNDATION

NATIONAL SCIENCE BOARD

WASHINGTON, D.C. 20550

LETTER TO GOVERNMENT AGENCY OFFICIALS RESPONSIBLE FOR SCIENCE AND TECHNOLOGY

Currently the National Science Board is preparing its Eighth Annual Report to the President and to the Congress. The report will concentrate on the circumstances which might affect the capacity of the Nation to continue a strong position in science and technology. It will attempt to identify and to study prospectively selected critical problems developing in the operating research sectors---namely, university, industry, Government laboratories and independent research institutes. The report is not as much concerned with dollar support as with circumstances in the institutional, managerial or policy environment which will influence the productivity of working scientists and engineers. In order to identify critical problems for the Government laboratories, the Committee on Eighth NSB Report is seeking input from selected agency officials with broad responsibilities for research.

The Committee would very much appreciate learning about the two most critical issues/problems facing fundamental (long term, basic) research, as you see it, in the near term future. "Near term future" means issues currently emerging or seen-to-be-emerging in the next decade or so. For example, as you look ahead, in your capacity as director of a government laboratory what problems do you anticipate? What critical issues/problems will condition scientific and technological research in government and will decrease its effectiveness unless properly addressed? Would you please order your issues/problems "one" and "two" and then provide a brief descriptive paragraph for each? Feel free to propose resolutions or solutions.

In addition to your view from the agency level, the Committee expects to obtain perceptions from selected directors of Government laboratories.

In the name of the National Science Board and its Committee on Eighth NSB Report, I thank you for a quick reply. If at all possible, we would very much appreciate having your comments within the next few weeks or so.

NATIONAL SCIENCE FOUNDATION

NATIONAL SCIENCE BOARD

WASHINGTON, D.C. 20550

LETTER TO DIRECTORS OF INTRAMURAL GOVERNMENT LABORATORIES

Currently the National Science Board is preparing its Eighth Annual Report to the President and to the Congress. The report will concentrate on the circumstances which might affect the capacity of the Nation to continue a strong position in science and technology. It will attempt to identify and to study prospectively selected critical problems developing in the operating research sectors---namely, university, industry, Government laboratories and independent research institutes. The report is not as much concerned with dollar support as with circumstances in the institutional, managerial or policy environment which will influence the productivity of working scientists and engineers.

In order to identify critical problems for the Government laboratories, the Committee on Eighth NSB Report earlier contacted Dr. Richard W. Roberts, Chairman of the Committee on Federal Laboratories, and asked him to express collective views on Government laboratories. Subsequently, the Committee decided to contact individual directors of research or vice presidents of research in university, industry, and independent research laboratories. To be consistent, the Committee has now expanded its inquiry to include individual directors of Government laboratories and is writing to a selected group of thirty.

The Committee would very much appreciate learning about the two most critical issues/problems facing fundamental (long term, basic) research, as you see it, in the near term future. "Near term future" means issues currently emerging or seen-to-be-emerging in the next decade or so. For example, as you look ahead, in your capacity as director of a government laboratory what problems do you anticipate? What critical issues/problems will condition scientific and technological research in Government laboratories and will decrease its effectiveness unless properly addressed? Would you please order your issues/problems "one" and "two" and then provide a brief descriptive paragraph for each? Feel free to propose resolutions or solutions.

In addition to your view from the research management level, the Committee expects to obtain perceptions from the agency level in a separate letter.

In the name of the National Science Board and its Committee on Eighth NSB Report, I thank you for a quick reply. If at all possible, we would very much appreciate having your comments within the next few weeks or so.

Many thanks for your time, interest, and effort. If you have any questions regarding this letter please contact Dr. James J. Zwolenik at 202-632-5786.

Very truly yours,

F. P. Thieme

NATIONAL SCIENCE FOUNDATION

NATIONAL SCIENCE BOARD

WASHINGTON, D.C. 20550

LETTER TO DIRECTORS
OF FFRDC's

Currently the National Science Board is preparing its Eighth Annual Report to the President and to the Congress. The report will concentrate on the circumstances which might affect the capacity of the Nation to continue a strong position in science and technology. It will attempt to identify and to study prospectively selected critical problems developing in the operating research sectors---namely, university, industry, Government laboratories and independent research institutes. The report is not as much concerned with dollar support as with circumstances in the institutional, managerial or policy environment which will influence the productivity of working scientists and engineers.

In order to identify critical problems for the Federally Funded Research and Development Centers, the Committee decided to contact the director of each center.

The Committee would very much appreciate learning about the two most critical issues/problems facing fundamental (long term, basic) research, as you see it, in the near term future. "Near term future" means issues currently emerging or seen-to-be-emerging in the next decade or so. For example, as you look ahead, in your capacity as director of an FFRDC, what problems do you anticipate? What critical issues/problems will condition scientific and technological research in FFRDC's and will decrease their effectiveness unless properly addressed? Would you please order your issues/problems "one" and "two" and then provide a brief descriptive paragraph for each? Feel free to propose resolutions or solutions.

In the name of the National Science Board and its Committee on Eighth NSB Report, I thank you for a quick reply. If at all possible, we would very much appreciate having your comments within the next few weeks or so.

Many thanks for your time, interest, and effort. If you have any questions regarding this letter please contact Dr. James J. Zwolenik at 202-632-5786.

Very truly yours,

F. P. Thieme

NATIONAL SCIENCE FOUNDATION

NATIONAL SCIENCE BOARD

WASHINGTON, D.C. 20550

LETTER TO PRESIDENTS OR DIRECTORS OF INDEPENDENT RESEARCH INSTITUTES

Currently the National Science Board is preparing its Eighth Annual Report to the President and to the Congress. The report will concentrate on the circumstances which might affect the capacity of the Nation to continue a strong position in science and technology. It will attempt to identify and to study prospectively selected critical problems developing in the operating research sectors--namely university, industry, Government laboratories and independent research institutes. The report is not as much concerned with dollar support as with circumstances in the institutional, managerial or policy environment which will influence the productivity of working scientists and engineers. In order to identify critical problems for the independent research institutes, the Committee on Eighth NSB Report is seeking input from selected individuals with direct responsibility for the vitality of research in independent research institutes.

The Committee would very much appreciate learning about the two most critical issues/problems facing fundamental (long term, basic) research, as you see it, in the near term future. "Near term future" means issues currently emerging or seen-to-be-emerging in the next decade or so. For example, as you look ahead, in your capacity as President of   what problems do you anticipate? What critical issues/problems will condition scientific and technological research in the independent research institute and will decrease its effectiveness unless properly addressed? Would you please order your issues/problems "one" and "two" and then provide a brief descriptive paragraph for each? Feel free to propose resolutions or solutions.

In the name of the National Science Board and its Committee on Eighth NSB Report, I thank you for a quick reply. If at all possible, we would very much appreciate having your comments within the next few weeks or so. An addressed, franked envelope is enclosed.

Appendix C
COMPLETE LIST OF RESPONDENTS TO NSB INQUIRY LETTER, BY SECTOR

The following tables list the respondents to the inquiry letter by sector. Those who actually sent a response letter are included, but not those who had a letter written on their behalf that was not over their name.

The respondents on the first two tables are in the university sector. One table is for Carnegie Research Universities I, the other for Research Universities II. Within a table, the universities are listed in alphabetical order. There are 50 Research Universities I and 42 Research Universities II, and there is at least one respondent from each of these. Respondents are listed by title under their universities.

There is a single table for all industry respondents. The corporations are listed alphabetically, and the individuals are listed by title under their corporations.

For the Government research sector, there are separate tables for agency officials, directors of intramural laboratories, and directors of FFRDC's. The table of agency officials is alphabetized by the name of the agency. The table of intramural laboratories is alphabetized by controlling agency, and under each agency by laboratory name. FFRDC's are listed simply by laboratory name. There is only one respondent from each intramural laboratory or FFRDC listed.

The last table lists the independent research institutes alphabetically. There is one respondent from each.

Table C-1.—List of Respondents from Research Universities I

University of Arizona

A. Richard Kassander, Jr.
Vice President, Research

Robert L. Hamblin
Head, Department of Sociology

Lee B. Jones
Head, Department of Chemistry

Roy H. Mattson
Head, Department of Electrical Engineering

California Institute of Technology

Harold Brown
President

A. J. Lindstrom
Sponsored Research Administrator

John D. Baldeschwieler
Chairman, Division of Chemistry and Chemical Engineering

M. Schmidt
Chairman, Division of Physics, Mathematics, and Astronomy

University of California, Berkeley

Albert H. Bowker
Chancellor

August G. Manza
Manager, Campus Research Office

Gerald D. Berreman
Chairman, Department of Anthropology

Daniel E. Koshland, Jr.
Chairman, Department of Biochemistry

Leonard Machlis
Chairman, Department of Botany

M. Rosenlicht
Chairman, Department of Mathematics

University of California, Davis

James H. Meyer
Chancellor

Ray B. Krone
Associate Dean for Research College of Engineering

R. W. Allard
Chairman, Department of Genetics

John L. Ingraham
Chairman, Department of Bacteriology

J. A. Jungerman
Director, Crocker Nuclear Laboratory

University of California, Los Angeles

Charles E. Young
Chancellor

Peter Likins
Associate Dean, School of Engineering and Applied Science

Table continues on next page

Table C-1 *continued*

Daniel Kivelson
Chairperson, Department of Chemistry

University of California, San Diego

W. D. McElroy
Chancellor

Roy D'Andrade
Chairman, Department of Anthropology

William R. Frazer
Chairman, Department of Physics

Carl W. Helstrom
Chairman, Department of Applied Physics and Information Science

Case Western Reserve University

Louis A. Toepfer
President

Harvey B. Willard
Vice Provost and Dean of Science

John P. Fackler, Jr.
Chairman, Department of Chemistry

Peter Pesch
Chairman, Department of Astronomy

University of Chicago

John T. Wilson
Provost and Acting President

Norman M. Bradburn
Chairman, Department of Behavioral Sciences

E. N. Parker
Chairman, Department of Astronomy and Astrophysics

J. A. Simpson
Director, Enrico Fermi Institute

University of Colorado, Main Campus

Lawson Crowe
Chancellor

Milton E. Lipetz
Vice Chancellor for Research and Dean of the Graduate School

Frank S. Barnes
Chairman, Department of Electrical Engineering

Bruce R. Ekstrand
Chairman, Department of Psychology

David A. Lind
Chairman, Department of Physics and Astrophysics

Stewart J. Strickler
Chairman, Department of Chemistry

Columbia University, Main Division

Virginia Lief
Director, Institutional Research & Budget Planning

Mitchell I. Ginsberg
Dean, School of Social Work

John H. Bryant
Director, School of Public Health

Robert A. Gross
Chairman, Department of Mechanical Engineering

Gilbert Stork
Chairman, Department of Chemistry

Cornell University, Main Campus

Dale R. Corson
President

W. D. Cooke
Vice President for Research

H. H. Johnson
Director, Materials Science Center

Raphael Littauer
Chairman, Department of Physics

Duke University

Terry Sanford
President

John C. McKinney
Vice Provost and Dean of the Graduate School

Donald J. Fluke
Chairman, Department of Zoology

Robert L. Hill
Chairman, Department of Biochemistry

Allen C. Kelley
Chairman, Department of Economics

L. D. Quin
Chairman, Department of Chemistry

University of Florida

Robert Q. Marston
President

George K. Davis
Director of Sponsored Research

Peter A. Cerutti
Chairman, Department of Biochemistry

A. E. S. Green
Director, Interdisciplinary Center for Aeronomy and (Other) Atmospheric Sciences

E. E. Muschlitz, Jr.
Chairman, Department of Chemistry

Otto von Mering
Acting Chairman, Department of Anthropology

University of Georgia

Fred C. Davison
President

Robert C. Anderson
Vice President for Research

Norman Herz
Head, Department of Geology

Milton H. Hodge
Head, Department of Psychology

Charles E. Melton
Head, Department of Chemistry

W. J. Payne
Head, Department of Microbiology

Harry D. Peck, Jr.
Head, Department of Biochemistry

Harvard University

Derek C. Bok
President

Y. C. Ho
Associate Dean, Division of Engineering and Applied Physics

Paul C. Martin
Former Chairman, Department of Physics

University of Hawaii, Main Campus

Douglas S. Yamamura
Acting Chancellor

Geoffrey C. Ashton
Acting Vice Chancellor

John T. Jefferies
Director, Institute for Astronomy

Donald M. Topping
Director, Social Sciences and Linguistics Institute

University of Illinois, Urbana

John E. Corbally
President, University of Illinois

George A. Russell
Vice Chancellor for Research and Dean of The Graduate College

R. D. DeMoss
Head, Department of Microbiology

H. S. Gutowsky
Director, School of Chemical Sciences

Joseph E. McGrath
Head, Department of Psychology

C. P. Siess
Head, Department of Civil Engineering

University of Iowa

Duane C. Spriestersbach
Vice President for Educational Development and Research, and Dean of the Graduate College

Jerry J. Kollros
Chairman, Department of Zoology

Samuel C. Patterson
Chairman, Department of Political Science

Carl S. Vestling
Head, Department of Biochemistry

Johns Hopkins University

Steven Muller
President

University of Kentucky

Otis A. Singletary
President

W. C. Royster
Dean of the Graduate School and Coordinator for Research

William Y. Adams
Chairman, Department of Anthropology

S. F. Conti
Director, School of Biological Sciences

Clifford J. Cremers
Chairman, Department of Mechanical Engineering

William D. Ehmann
Chairman, Department of Chemistry

Fred W. Zechman
Chairman, Department of Physiology and Biophysics

University of Maryland, Main Campus

Robert E. Menzer
Associate Dean for Graduate Studies

John O. Corliss
Chairman, Department of Zoology

J. K. Goldhaber
Chairman, Department of Mathematics

Massachusetts Institute of Technology

Jerome B. Wiesner
President

William F. Pounds
Dean, Sloan School of Management

Herman Feshbach
Chairman, Department of Physics

University of Miami

Henry King Stanford
President

Eugene H. Man
Dean, Research Coordination

Cesare Emiliani
Chairman, Department of Geology

Joseph G. Hirschberg
Chairman, Department of Physics

Marshall R. Jones
Chairman, Department of Psychology

T. Nejat Veziroglu
Chairman, Department of Mechanical Engineering

Michigan State University

Clifton R. Wharton, Jr.
President

Milton E. Muelder
Vice President for Research and Development

Robert Barker
Chairman, Department of Biochemistry

J. W. Butcher
Chairman, Department of Zoology

Truman O. Woodruff
Chairman, Department of Physics

University of Michigan, Main Campus

Charles G. Overberger
Vice President for Research University of Michigan

Thomas M. Dunn
Chairman, Department of Chemistry

G. I. Haddad
Chairman, Department of Electrical and Computer Engineering

Robert M. Howe
Chairman, Department of Aerospace Engineering

Daniel Sinclair
Chairman, Department of Physics

J. E. Keith Smith
Chairman, Department of Psychology

University of Minnesota, Minneapolis-St. Paul

Henry Koffler
Vice President for Academic Affairs

Rutherford Aris
Head, Department of Chemical Engineering and Materials Science

Lloyd H. Lofquist
Chairman, Department of Psychology

Johannes C. C. Nitsche
Head, School of Mathematics

F. E. Shideman
Head, Department of Pharmacology

N. J. Simler
Chairman, Department of Economics

University of Missouri, Columbia

A. H. Emmons
Vice President for Research University of Missouri

Herbert W. Schooling
Chancellor

James O. Davis
Chairman, Department of Physiology

E. C. A. Runge
Chairman, Department of Agronomy

Robert W. Murray
Chairman, Department of Chemistry St. Louis Campus

Dale A. Neuman
Chairman, Political Science Department, Kansas City Campus

Laird D. Schearer
Chairman, Department of Physics Rolla Campus

New York University

James M. Hester
President

Sidney G. Roth
Vice Chancellor for Federal Relations

Alvin I. Kosak
Chairman, Department of Chemistry

G. Stotzky
Chairman, Department of Biology

North Carolina State University, Raleigh

John T. Caldwell
Chancellor

Earl G. Droessler
Dean for Research Administration

Thomas S. Elleman
Head, Department of Nuclear Engineering

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D.D. Mason
Head, Department of Statistics

Samuel B. Tove
Head, Department of Biochemistry

University of North Carolina, Chapel Hill

George R. Holcomb
Dean, Research Administration

Russell F. Christman
Chairman, Department of Environmental Sciences and Engineering

James H. Crawford, Jr.
Chairman, Department of Physics and Astronomy

Thomas L. Isenhour
Chairman, Department of Chemistry

G. P. Manire
Chairman, Department of Bacteriology and Immunology

Northwestern University

Robert H. Strotz
President

David Mintzer
Vice President for Research and Dean of Science

Robert L. Letsinger
Chairman, Department of Chemistry

Neena B. Schwartz
Chairman, Department of Biological Sciences

Daniel Zelinsky
Chairman, Department of Mathematics

Ohio State University, Main Campus

Jules B. LaPidus
Vice Provost and Dean

Leon M. Dorfman
Chairman, Department of Chemistry

Samuel H. Osipow
Chairman, Department of Psychology

Tony J. Peterle
Chairman, Department of Zoology

M. O. Thurston
Chairman, Department of Electrical Engineering

Pennsylvania State University, Main Campus

R. G. Cunningham
Vice President for Research and Graduate Studies

Paul Ebaugh
Associate Dean for Research College of Engineering

Lee C. Eagleton
Head, Department of Chemical Engineering

Barnes W. McCormick
Head, Department of Aerospace Engineering

University of Pennsylvania

Martin Meyerson
President

Reagan A. Scurlock
Director of Research Administration

Campbell Laird
Chairman, Department of Metallurgy and Materials Science

Daniel D. Perlmutter
Chairman, Department of Chemical and Biochemical Engineering

Walter D. Wales
Chairman, Department of Physics

David White
Chairman, Department of Chemistry

University of Pittsburgh, Main Campus

Keith Brown
Chairman, Department of Anthropology

A. David Lazovik
Chairman, Department of Psychology

Philip Stehle
Chairman, Department of Physics

W. E. Wallace
Chairman, Department of Chemistry

Princeton University

Sheldon Judson
Chairman, University Research Board

Marvin Bressler
Chairman, Department of Sociology

Sam Glucksberg
Chairman, Department of Psychology

Leon Lapidus
Chairman, Department of Chemical Engineering

Lyman Spitzer, Jr.
Chairman, Department of Astrophysical Sciences

Purdue University, Main Campus

Arthur G. Hansen
President

F. N. Andrews
Vice President for Research and Dean of the Graduate School

Struther Arnott
Head, Department of Biological Sciences

Robert A. Benkeser
Head, Department of Chemistry

C. L. Coates
Head, School of Electrical Engineering

James C. Naylor
Head, Department of Psychological Sciences

University of Rochester

David A. McBride
Director of Research and Project Administration

Paul Horowicz
Chairman, Department of Physiology

A. C. Melissinos
Chairman, Department of Physics and Astronomy

William H. Riker
Chairman, Department of Political Science

Rockefeller University

Albert Gold
Vice President for Academic Research

Rutgers University, New Brunswick

Edward J. Bloustein
President

James W. Green
Acting Dean, The Graduate School

Saul Amarel
Chairman, Department of Computer Science

Michael R. D'Amato
Chairman, Department of Psychology

J. A. Sauer
Chairman, Department of Mechanics and Materials Science

Benjamin B. Stout
Chairman of Biological Sciences

Harold S. Zapolsky
Chairman, Department of Physics

University of Southern California

Zohrab A. Kaprielian
Vice President, Academic Administration and Research

Stanford University

William F. Massy
Vice Provost for Research

Daniel D. Federman
Chairman, Department of Medicine

Joshua Lederberg
Chairman, Department of Genetics

John G. Linvill
Chairman, Department of Electrical Engineering

W. Richard Scott
Executive Head, Department of Sociology

E. E. van Tamelen
Chairman, Department of Chemistry

University of Tennessee, Knoxville

Edward J. Boling
President

Carl O. Thomas
Dean for Research

C. W. Keenan
Associate Dean, College of Liberal Arts

Kenneth W. Heathington
Director, Transportation Center

Homer F. Johnson
Head, Department of Chemical and Metallurgical Engineering

Texas A&M University

Jack K. Williams
President

Robert R. Berg
Director, Office of University Research

Newton C. Ellis
Head, Department of Industrial Engineering

Richard A. Geyer
Head, Department of Oceanography

John Richard Seed
Head, Department of Biology

University of Texas, Austin

George R. Blitch
Director of Research Management

Philip B. Gough
Chairman, Department of Psychology

Thomas A. Griffy
Chairman, Department of Physics

Harlan J. Smith
Chairman, Department of Astronomy and Director, McDonald Observatory

University of Utah

David P. Gardner
President

W. S. Partridge
Vice President for Research

Edward M. Eyring
Chairman, Department of Chemistry

Richard W. Grow
Chairman, Department of Electrical Engineering

S. H. Ward
Chairman, Department of Geology and Geophysics

Vanderbilt University

Alexander Heard
Chancellor

Howard L. Hartman
Dean, School of Engineering

Wendell G. Holladay
Dean, College of Arts and Science

Mark M. Jones
Chairman, Department of Chemistry

Oscar Touster
Chairman, Department of Molecular Biology

Mayer N. Zald
Chairman, Department of Sociology and Anthropology

Washington University, St. Louis

William H. Danforth
Chancellor

Linda S. Wilson
Associate Vice Chancellor for Research

W. M. Cowan
Director, Division of Biology and Biomedical Sciences

Jerome R. Cox, Jr.
Chairman, Department of Computer Science

Luis Glaser
Chairman, Department of Biological Chemistry

R. E. Norberg
Chairman, Department of Physics

T. T. Sandel
Chairman, Department of Psychology

University of Washington

John R. Hogness
President

Daniel G. Dow
Chairman, Department of Electrical Engineering

Ernest M. Henley
Chairman, Department of Physics

Earl Hunt
Chairman, Department of Psychology

Douglass C. North
Chairman, Department of Economics

University of Wisconsin, Madison

Edwin Young
Chancellor

William C. Burns
Chairman, Department of Zoology

Marvin E. Ebel
Chairman, Department of Physics

Warren E. Stewart
Chairman, Department of Chemical Engineering

Yale University

Arthur M. Ross
Assistant to the Deputy Provost for the Sciences

D. Allan Bromley
Chairman, Department of Physics

Wendell R. Garner
Chairman, Department of Psychology

James Tobin
Chairman, Department of Economics

Charles A. Walker
Chairman, Department of Engineering and Applied Science

Yeshiva University

Joshua A. Fishman
Vice President for Academic Affairs

Lewis Coburn
Chairman, Department of Mathematics

Joel L. Lebowitz
Chairman, Department of Physics

Dominick P. Purpura
Chairman, Department of Neurological Science

Sam Seifter
Chairman, Department of Biochemistry

Lillian J. Zach
Chairman, Department of Psychology

Table C-2.—List of Respondents from Research Universities II

University of Arkansas, Main Campus

Charles E. Bishop
President

Aubrey E. Harvey
Coordinator of University Research

D. A. Hinkle
Head, Department of Agronomy

Lester C. Howick
Chairman, Department of Chemistry

F. D. Miner
Head, Department of Entomology

Auburn University, Main Campus

Harry M. Philpott
President

Chester C. Carroll
Vice President for Research

Howard Carr
Head, Department of Physics

B. Eugene Griessman
Head, Department of Sociology and Anthropology

J. David Irwin
Head, Department of Electrical Engineering

Donald M. Vestal, Jr.
Head, Department of Mechanical Engineering

Boston University

John R. Silber
President

Bayley F. Mason
Vice President for Resources

Norman N. Lichtin
Chairman, Department of Chemistry

Michael D. Papagiannis
Chairman, Department of Astronomy

George O. Zimmerman
Chairman, Department of Physics

Brandeis University

Marver H. Bernstein
President
and
Jack S. Goldstein
Dean of Faculty

Sanford M. Birnbaum
Administrator of Sponsored Programs

Harlyn O. Halvorson
Director, Rosenstiel Basic Medical Sciences Research Center

Jerome P. Levine
Chairman, Department of Mathematics

Brown University

Maurice Glicksman
Dean of the Graduate School

Elizabeth H. Leduc
Dean of the Division of Biological and Medical Sciences

Rodney J. Clifton
Chairman, Executive Committee, Division of Engineering

Jack K. Hale
Chairman, Division of Applied Mathematics

Robert M. Marsh
Chairman, Department of Sociology

Phillip J. Stiles
Chairman, Department of Physics

Carnegie-Mellon University

Richard M. Cyert
President

Edward R. Schatz
Provost and Vice President for Academic Affairs

Tomlinson Fort, Jr.
Head, Department of Chemical Engineering

S. A. Friedberg
Chairman, Department of Physics

Lester B. Lave
Head, Department of Economics

J. F. Traub
Head, Department of Computer Science

Catholic University of America

Clarence C. Walton
President

Benedict T. DeCicco
Chairman, Department of Biology

University of Cincinnati, Main Campus

Frank R. Tepe, Jr.
Assistant University Dean for Graduate Education and Research

Claremont Graduate School

Barnaby C. Keeney
President

Paul A. Albrecht
Dean

Colorado State University

A. R. Chamberlain
President

George G. Olson
Vice President for Research

J. W. N. Fead
Head, Department of Civil Engineering

University of Connecticut, Main Campus

Glenn W. Ferguson
President

Hugh Clark
Associate Dean, The Graduate School

Joseph I. Budnick
Chairman, Department of Physics

William V. D'Antonio
Chairman, Department of Sociology

A. T. DiBenedetto
Head, Department of Chemical Engineering

William K. Purves
Executive Officer, The Biological Sciences Group

W. R. Vaughan
Head, Department of Chemistry

Emory University, Main Campus

Sanford S. Atwood
President

Asa A. Humphries, Jr.
Chairman, Department of Biology

Leon Mandell
Chairman, Department of Chemistry

Florida State University

Stanley Marshall
President

Robert M. Johnson
Provost, Graduate Studies and Research

Walter Dick
Leader, Instructional Design and Development Program

Steve Edwards
Chairman, Department of Physics

George Washington University

Carl J. Lange
Assistant Vice President for Research

Louis H. Mayo
Director, Program of Policy Studies in Science and Technology

Charles T. Stewart
Chairman, Department of Economics

Richard D. Walk
Chairman, Department of Psychology

Georgia Institute of Technology, Main Campus

Thomas E. Stelson
Vice President for Research

J. A. Bertrand
Director, School of Chemistry

A. L. Ducoffe
Director, School of Aerospace Engineering

W. Denney Freeston, Jr.
Director, School of Textile Engineering

Demetrius T. Paris
Director, School of Electrical Engineering

Illinois Institute of Technology

Thomas L. Martin, Jr.
President

Sidney A. Guralnick
Dean of the Graduate School

Leonard I. Grossweiner
Chairman, Department of Physics

David B. Hershenson
Chairman, Department of Psychology and Education

Sudhir Kumar
Chairman, Department of Mechanics and Mechanical and Aerospace Engineering

D. T. Wasan
Chairman, Department of Chemical Engineering

Indiana University, Bloomington

Dean Fraser
Chairman, Department of Microbiology

Irving J. Saltzman
Chairman, Department of Psychology

John H. Sinclair
Chairman, Department of Zoology

Maynard Thompson
Chairman, Department of Mathematics

Iowa State University of Science and Technology

W. Robert Parks
President

George Burnet
Head, Department of Chemical Engineering and Nuclear Engineering

Carl E. Ekberg, Jr.
Head, Department of Civil Engineering

R. E. McCarley
Chairman, Department of Chemistry

Kansas State University of Agriculture and Applied Sciences

James A. McCain
President

R. F. Kruh
Dean of the Graduate School

David J. Cox
Head, Department of Biochemistry

William G. Fateley
Head, Department of Chemistry

C. E. Hathaway
Head, Department of Physics

University of Kansas

Archie R. Dykes
Chancellor

Henry L. Snyder
Dean, Research Administration

Brower R. Burchill
Chairman, Division of Biological Sciences

J. A. Landgrebe
Chairman, Department of Chemistry

Louisiana State University, Baton Rouge

Paul W. Murrill
Chancellor

R. G. Goodrich
Chairman, Department of Physics and Astronomy

J. A. Polack
Head, Department of Chemical Engineering

Laurence Siegel
Chairman, Department of Psychology

University of Massachusetts, Amherst

Randolph W. Bromery
Chancellor

N. J. Demerath, III
Chairman, Department of Sociology

John W. Donahoe
Acting Chairman, Department of Psychology

R. C. Fuller
Chairman, Department of Biochemistry

Roger S. Porter
Head, Department of Polymer Science and Engineering

Merit P. White
Head, Department of Civil Engineering

Mississippi State University

William L. Giles
President

J. Chester McKee
Vice President for Research and Dean of The Graduate School

B. J. Ball
Head, Department of Electrical Engineering

Donald W. Emerich
Head, Department of Chemistry

James D. Lancaster
Agronomist, Department of Agronomy

John T. Morrow
Professor, Department of Zoology

John Saunders
Head, Department of Sociology

University of Nebraska, Main Campus

James H. Zumberge
Chancellor

Duane Acker
Vice Chancellor

W. E. Splinter
Chairman, Department of Agricultural Engineering

Glen J. Vollmar
Chairman, Department of Agricultural Economics

Table continues on next page

Table C-2 *continued*

City University of New York, Graduate Center

Max K. Hecht
Chairman, Department of Biology Queens College

State University of New York, Buffalo, Main Campus

Albert Somit
Executive Vice President

Robert C. Fitzpatrick
Acting Vice-President for Research

Stanley Bruckenstein
Chairman, Department of Chemistry

Paul L. Garvin
Chairman, Department of Linguistics

Chester C. Langway, Jr.
Chairman, Department of Geological Sciences

George C. Lee
Chairman, Department of Civil Engineering

Lester W. Milbrath
Director, Social Science Research Institute

Donald B. Rosenthal
Vice Chairman, Department of Political Science

Oklahoma State University, Main Campus

James H. Boggs
Vice President for Academic Affairs

William L. Hughes
Head, School of Electrical Engineering

W. E. Jaynes
Head, Department of Psychology

Roger E. Koeppe
Head, Department of Biochemistry

W. A. Sibley
Head, Department of Physics

University of Oklahoma, Main Campus

Charles W. Bert
Director, School of Aerospace, Mechanical, and Nuclear Engineering

Victor H. Hutchison
Chairman, Department of Zoology

Charles J. Mankin
Director, School of Geology and Geophysics

Thomas J. Wilbanks
Chairman, Department of Geography

Oregon State University

Robert MacVicar
President

Roy A. Young
Vice President for Research and Graduate Studies

P. R. Elliker
Chairman, Department of Microbiolog'

E. Wendell Hewson
Chairman, Department of Atmospheric Sciences

Thomas C. Moore
Chairman, Department of Botany and Plant Pathology

David P. Shoemaker
Chairman, Department of Chemistry

University of Oregon, Main Campus

Aaron Novick
Dean, The Graduate School

Marvin D. Girardeau
Chairman, Department of Physics

F. W. Munz
Acting Head, Department of Biology

Richard M. Noyes
Head, Department of Chemistry

Peter H. von Hippel
Director, Institute of Molecular Biology

Rice University

Norman Hackerman
President
and
W. E. Gordon
Dean of Science and Engineering
and
G. J. Schroepfer, Jr.
Chairman, Department of Biochemistry

John L. Margrave
Dean, Advanced Studies and Research

J. L. Franklin
Chairman, Department of Chemistry

J. D. Hellums
Chairman, Department of Chemical Engineering

Robert M. Thrall
Chairman, Department of Mathematical Sciences

G. K. Walters
Chairman, Department of Physics

Syracuse University

Melvin A. Eggers
Chancellor

D. E. Kibbey
Vice President for Research and Graduate Affairs

Nathan Ginsburg
Chairman, Department of Physics

Donald G. Lundgren
Chairman, Department of Biology

'Kin N. Tong
Chairman, Department of Mechanical and Aerospace Engineering

Temple University

Edwin P. Adkins
Associate Vice President Research and Program Development

David G. Berger
Chairman, Department of Sociology

Stephen T. Takats
Professor, Department of Biology

Tufts University

Burton C. Hallowell
President

A. M. Cormack
Chairman, Department of Physics

Arthur Uhlir, Jr.
Chairman, Department of Electrical Engineering

Tulane University

Herbert E. Longenecker
President

Peter J. Gerone
Director, Delta Regional Primate Research Center

University of Virginia, Main Campus

Frank L. Hereford, Jr.
President

David A. Shannon
Vice President and Provost

A. R. Kuhlthau
Chairman, Department of Engineering Science and Systems

Kevin McCrimmon
Chairman, Department of Mathematics

Oscar L. Miller, Jr.
Chairman, Department of Biology

Richard T. Selden
Chairman, Department of Economics

Virginia Polytechnic Institute and State University

W. E. Lavery
President

Randal M. Robertson
Dean, Research Division

Alan Walter Steiss
Associate Dean College of Architecture

Alan F. Clifford
Head, Department of Chemistry

Daniel Frederick
Head, Engineering Science and Mechanics Department

James McD. Grayson
Head, Department of Entomology

Wilson Schmidt
Head, Department of Economics

Washington State University

Glenn Terrell
President

C. J. Nyman
Dean, The Graduate School

Roger D. Willett
Chairman, Department of Chemistry

Wayne State University

Thomas J. Curtin
Director, Research and Sponsored Programs Service

G. B. Beard
Chairman, Department of Physics

J. Ross Eshleman
Chairman, Department of Sociology

John D. Taylor
Chairman, Department of Biology

West Virginia University, Main Campus

James G. Harlow
President

Ray Koppelman
Provost for Research and Graduate Studies

Roger F. Maley
Chairman, Department of Psychology

Neil A. Palomba
Chairman, Department of Economics

W. E. Vehse
Chairman, Department of Physics

C. Y. Wen
Chairman, Department of Chemical Engineering

Table C-3.—List of Respondents from Industry

Allegheny Ludlum Industries, Inc.

Robert J. Buckley
President

Allied Chemical

David H. Bradford, Jr.
President

Robert G. Denkewalter
Vice President, Research & Technology

Allis-Chalmers Corporation

Gerald T. Petersen
Director, Advanced Technology Center

Robert B. Benson
Director of Patent Law Department

Aluminum Company of America

W. H. Krome George
President & Chief Executive Officer

Allen S. Russell
Vice President, Alcoa Laboratories

American Can Company

Herbert E. Hirschland
Vice President, Technology & Development

Ampex Corporation

Victor E. Ragosine
Vice President-General Manager
Advanced Technology Division

Anheuser-Busch, Inc.

R. A. Clayton
Director of Research

Armco Steel Corporation

L. F. Weitzenkorn
Senior Vice President
Research & Technology

Armstrong Cork Company

J. E. Hazeltine, Jr.
Vice-President and
Director of Research

AVCO Corporation

George L. Hogeman
President and Chief Operating Officer

Avery Products Corporation

Ernest F. Hare
Senior Member, Technical Staff

Baxter Laboratories, Inc.

Richard S. Wilbur
Senior Vice President

Bechtel Corporation

D. Furlong
Vice President

Bell Laboratories

N. B. Hannay
Vice President
Research and Patents

Bell & Howell

Dexter P. Cooper, Jr.
Vice President

Bethlehem Steel Corporation

D. J. Blickwede
Vice President and
Director of Research

The Boeing Company

George S. Schairer
Vice President - Research

Borg-Warner Corporation

Donald W. Collier
Vice President - Technology

Burlington Industries, Inc.

George E. Norman, Jr.
Vice President

Carnation Company

J. M. McIntire
General Manager of Research

Celanese Corporation

Reiner G. Stoll
Vice President - Technical Director

The Coca-Cola Company

Roberto C. Goizueta
Executive Vice President, Technical

Darshan S. Bhatia
Director of Research

Commonwealth Edison

E. J. Steeve
Research Engineer

Consolidation Coal Company, Inc.

W. N. Poundstone
Executive Vice President

Continental Can Company, Inc.

Robert E. Mesrobian
Vice President, Research & Engineering

Cutter Laboratories, Inc.

Kenneth E. Hamlin
Senior Vice President, Research & Quality Assurance

Dow Chemical U.S.A.

M. E. Pruitt
Vice President and Director of Research and Development U.S.

Eastman Kodak Company

Wesley T. Hanson, Jr.
Vice President and Director Research Laboratories

E. I. du Pont de Nemours & Company, Inc.

E. R. Kane
President

Eli Lilly and Company

C. W. Pettinga
Executive Vice President

Environmental Research and Technology, Inc.

Robert A. Stauffer
Vice President

Exxon Research and Engineering Company

N. V. Hakala
President

Fairchild Camera and Instrument Corporation

James M. Early
Division Vice President Fairchild Research and Development Division

Ford Motor Company

Lee A. Iacocca
President

W. Dale Compton
Vice President, Scientific Research

The Foxboro Company

John W. Bernard
Director of Research

The Gates Rubber Company

George H. Jenkins
Vice President

General Electric Company

Reginald H. Jones
Chairman of the Board

Arthur M. Bueche
Vice President Research and Development

General Foods Corporation

A. S. Clausi
Vice President, Corporate Research

General Motors Corporation

Paul F. Chenea
Vice President

General Technical Services, Inc.

A. S. Iberall
Chief Scientist and President

The B. F. Goodrich Company

Robert J. Fawcett
Vice President Research and Development

The Goodyear Tire and Rubber Company

John H. Gerstenmaier
President

Gulf Oil Corporation

James E. Lee
President

Gulf Research and Development Company

T. R. Hopkins
President

Honeywell, Inc.

Van W. Bearinger
Vice President Science and Engineering

International Business Machines Corporation

Lewis M. Branscomb
Vice President and Chief Scientist

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Table C-3 *continued*

Ralph E. Gomory
Vice President and
Director of Research

International Telephone and Telegraph Corp.

Albert E. Cookson
Senior Vice President
General Technical Director

Johnson & Johnson

Foster B. Whitlock
Vice Chairman of the Board

Johnson & Johnson International

R. A. Fuller
Vice Chairman

S. C. Johnson and Son, Inc.

Ward J. Haas
Vice President
Corporate Research and Development

Jones & Laughlin Steel Corporation

James T. Bradford, Jr.
Vice President, Research & Engineering

Kaiser Aluminum & Chemical Corporation

D. J. McPherson
Vice President and Director
of Technology

Koppers Company, Inc.

William N. Maclay
Vice President and Director of Research

Wayne E. Kuhn

Professional Engineer

Lever Brothers Company, Inc.

Frank H. Healey
Research Vice President

Lockheed Aircraft Corporation

A. Carl Kotchian
President

Willis M. Hawkins
Senior Advisor

Mallinckrodt Chemical Works

George B. Vermont
Director, Research & Development
Food, Drug & Cosmetic Chemicals

P. R. Mallory & Co., Inc.

S. P. Wolsky
Director, Research & Development

Merck Sharp & Dohme Research Laboratories

Harry J. Robinson
Vice President for Scientific Affairs

Mine Safety Appliances Company

Frank W. Smith
Vice President

Minnesota Mining and Manufacturing Company

Robert M. Adams
Vice President, Research & Development

Monsanto Company

B. L. Williams
Director, Corporate Research

Motorola Inc.

Daniel E. Noble
Chairman, Science Advisory Board

Northrop Corporation

Kent Kresa
Vice President & Manager

PPG Industries, Inc.

H. W. Rahn
Director, Research & Development
Chemical Division

Packard Instrument Company, Inc.

Edward J. Rapetti
President

Pfizer Inc.

Gerald D. Laubach
President

Polaroid Corporation

Sheldon A. Buckler
Vice President

The Proctor & Gamble Company

John G. Smale
President

H. Tecklenburg
Vice President, Research & Development

RCA

James Hillier
Executive Vice President
Research and Engineering

Raytheon Company

Thomas L. Phillips
Chairman

Rockwell International

C. J. Meechan
Vice President, Research and Engineering

St. Regis Paper Company

I. H. Stockel
Director, Research & Development

Scott Paper Company

Vincent A. Russo
Division Vice President
Research & Development

Shell Oil Company

H. Bridges
President

The Singer Company

John K. Bragg
Director of Research

Sperry Rand Corporation

R. E. McDonald
President

Leonard Swern
Director of Technical Programs

Sprague Electric Company

Sidney D. Ross
Director, Corporate Research & Development

Standard Oil Company of California

E. D. Kane
Vice President

Chevron Oil Field Research Company

N. A. Riley
President

J. P. Stevens and Company, Inc.

Frank X. Werber
Vice President
Research & Development

Swift & Company

Richard A. Greenberg
Vice President, Research & Development

Texaco Inc.

John K. McKinley
President

Texas Instruments Incorporated

Mark Shepherd, Jr.
President

TRW Inc.

Ruben F. Mettler
President

David B. Langmuir
Research Consultant
TRW Systems Group

Union Carbide Corporation

Thomas R. Miller
Vice President

United States Gypsum Company

J. N. Walker
Director, Research & Development

United States Steel Corporation

J. R. Ferguson, Jr.
Executive Vice President,
Engineering and Research

John H. Gross
Director - Research

Universal Oil Products Company

J. O. Logan
President and Chairman of the Board

Vladimir Haensel
Vice President, Science and Technology

The Upjohn Company

W. N. Hubbard, Jr.
President

Varian Associates

Norman F. Parker
President

Warner-Lambert Company

D. A. Buyske
Vice President
Research & Development
Professional Products Group

Table continues on next page

Table C-3 *continued*

Westinghouse Electric Corporation

George F. Mechlin
Vice President, Research

Westvaco

Alfred H. Nissan
Vice President and
Corporate Research Director

Weyerhaeuser Company

A. S. Gregory
Director
Central Research and Development

Whittaker Corporation

Joseph F. Alibrandi
President

Joseph Kleiman
Senior Vice President

Rex Gosnell
Division Manager

Xerox Corporation

A. R. McCardell
President

George L. Pake
Vice President

Table C-4.—List of Respondents Responsible for R&D at Government Departments and Agencies

Department of Agriculture

T. W. Edminster
Administrator
Agricultural Research Service

Department of Commerce

Betsy Ancker-Johnson
Assistant Secretary for
Science and Technology

Department of Defense

Malcolm R. Currie
Director of Defense Research
and Engineering

Energy Research and Development Administration

John M. Teem
Assistant Administrator for Solar, Geothermal
and Advanced Energy Systems

Environmental Protection Agency

Wilson K. Talley
Assistant Administrator for
Research and Development

Department of Health, Education, and Welfare

Philip S. Chen, Jr.
Assistant Director for
Intramural Affairs
National Institutes of Health

National Aeronautics and Space Administration

John E. Naugle
Acting Associate Administrator

Department of Transportation

William C. Steber
Deputy Assistant Secretary for Systems
Engineering

Table C-5.—List of Respondents from Intramural Federal Laboratories

Department of Agriculture

Forest Products Laboratory
Jerome F. Saeman
Acting Director

National Animal Disease Center
Phillip A. O'Berry
Director

Eastern Regional Research Center
I. A. Wolff
Director

Northern Regional Research Center
W. H. Tallent
Acting Center Director

Western Regional Research Laboratory
A. I. Morgan, Jr.
Director

Department of Commerce

National Bureau of Standards
Richard W. Roberts
Director

National Oceanic and Atmospheric Administration
Environmental Research Laboratories
W. N. Hess
Director

Department of Defense

Aerospace Research Laboratories (AFSC)
Robert W. Milling
Commander

Air Force Cambridge Research Laboratories (AFSC)
Bernard S. Morgan, Jr.
Commander

Harry Diamond Laboratories
William W. Carter
Technical Director, Acting

Naval Research Laboratory
J. T. Geary
Director

Naval Surface Weapons Center
J. E. Colvard
Technical Director

Naval Weapons Center
G. L. Hollingsworth
Technical Director

Picatinny Arsenal
Harry W. Painter
Technical Director

U. S. Army Ballistic Research Laboratories
R. J. Eichelberger
Director

U.S. Army Missile Research, Development and Engineering Laboratory
John L. McDaniel
Director

U.S. Army Natick Development Center
Rufus E. Lester, Jr.
Commanding Officer

Department of Health, Education and Welfare

Center for Disease Control
Roslyn Q. Robinson
Director, Bureau of Laboratories

National Institute of Mental Health
John C. Eberhart
Director of Intramural Research

Department of the Interior

Bureau of Mines
Salt Lake City Metallurgy Research Center
Joe B. Rosenbaum
Consulting Metallurgist

Fish and Wildlife Service
Robert E. Putz
Deputy Associate Director - Research

National Aeronautics and Space Administration

Ames Research Center
Hans Mark
Director

George C. Marshall Space Flight Center
W. R. Lucas
Director

Goddard Space Flight Center
Michael J. Vaccaro
Associate Deputy Director

Langley Research Center
Edgar M. Cortright
Director

Lewis Research Center
Bruce T. Lundin
Director

Department of Transportation

Transportation Systems Center
Robert K. Whitford
Acting Director

Table C-6.—List of Respondents from Federally Funded Research and Development Centers

The Aerospace Corporation
Ivan A. Getting
President

Ames Laboratory ERDA
(Iowa State University of Science and Technology)
Robert S. Hansen
Director

Analytic Services, Inc. (ANSER)
Stanley J. Lawwill
President

Applied Physics Laboratory
(The Johns Hopkins University)
A. Kossiakoff
Director

Applied Research Laboratory
(The Pennsylvania State University)
John C. Johnson
Director

Argonne National Laboratory
(University of Chicago and Argonne Universities Assn.)
Robert G. Sachs
Director

Atomic Bomb Casualty Commission (ceased April 1, 1975)
National Academy of Sciences
Aaron Rosenthal
Comptroller - NAS

Brookhaven National Laboratory
(Associated Universities, Inc.)
George H. Vineyard
Director

Cerro-Tololo Inter-American Observatory
(Association of Universities for Research in Astronomy, Inc.)
Victor M. Blanco
Director

Fermi National Accelerator Laboratory
(Universities Research Association, Inc.)
Edwin L. Goldwasser
Deputy Director

Hanford Engineering Development Laboratory
(Westinghouse Hanford Company)
A. Squire
Director

Institute for Defense Analyses (IDA)
S. J. Deitchman
Assistant Vice President for Research

Kitt Peak National Observatory
(Association of Universities for Research in Astronomy, Inc.)
Leo Goldberg
Director

Lawrence Berkeley Laboratory
(University of California)
Andrew M. Sessler
Director

Lincoln Laboratory
(Massachusetts Institute of Technology)
Walter E. Morrow, Jr.
Associate Director

Liquid Metal Engineering Center
(Rockwell International Corporation)
J. C. Cochran
Vice President

Los Alamos Scientific Laboratory
(University of California)
H. M. Agnew
Director

National Center for Atmospheric Research
(University Corporation for Atmospheric Research)
John W. Firor
Executive Director

National Radio Astronomy Observatory
(Associated Universities, Inc.)
D. S. Heeschen
Director

Pacific Northwest Laboratories
(Battelle)
Edward L. Alpen
Director

RAND Corporation
Donald B. Rice
President

Savannah River Laboratory
(E. I. du Pont de Nemours & Company, Inc.)
C. H. Ice
Director

Stanford Linear Accelerator Center
(Stanford University)
W. K. H. Panofsky
Director

Space Radiation Effects Laboratory
(College of William and Mary)
Robert T. Siegel
Director

Table C-7.—List of Respondents from Independent Research Institutes

American Institutes for Research in the Behavioral Sciences
Paul A. Schwarz
President

Battelle Memorial Institute
S. L. Fawcett
President

Boyce Thompson Institute for Plant Research, Inc.
R. H. Wellman
Managing Director

Forsyth Dental Center
John W. Hein
Director

The Franklin Institute
Bowen C. Dees
President

Hudson Institute
Herman Kahn
Director

Institutes of Medical Sciences
George Z. Williams
Director, Institute of Health Research

Mayo Foundation
Atherton Bean
Chairman

Midwest Research Institute
John McKelvey
President

National Bureau of Economic Research, Inc.
John R. Meyer
President

National Opinion Research Center
Norman M. Bradburn
President

Oklahoma Medical Research Foundation
Clayton S. White
President

Oregon Regional Primate Research Center
William Montagna
Director

The Public Health Research Institute of the City of New York, Inc.
George K. Hirst
President and Director

Research for Better Schools, Inc.
Robert G. Scanlon
Executive Director

The Salk Institute
Frederic de Hoffmann
President

Southern Research Institute
R. D. Osgood, Jr.
Executive Vice President

Southwest Research Institute
Martin Goland
President

Stanford Research Institute
Charles A. Anderson
President and Chief Executive Officer

Syracuse University Research Corporation
Charles R. Wayne
Executive Vice President and General Manager

University City Science Center
Randall M. Whaley
President

Appendix D
COMPLETE LIST OF ISSUES TAKEN FROM THE RESPONSE LETTERS

This appendix lists all the issues taken from the response letters, if they were mentioned frequently enough to be made categories in the content analysis. Thus the very infrequently mentioned problems or solutions are not listed. The issues from each research sector are shown on a separate table. On each table, the issues for that sector are listed approximately in the order of their frequency of mention by all the respondents for that sector taken together. Appendix E shows the order of mention of the most frequently mentioned issues by the various classes of respondents within each sector.

Table D-1.—Complete List of Issues Taken from University Sector

There is pressure for applied research in preference to basic or pure research; projects are overly "targeted" or their subjects too minutely defined.
There is need for more continuity and stability in government funding of research; research grants should be longer.
Hiring and research support problems are experienced by younger faculty; departments cannot hire because of tenure—older faculty do not leave.
The continued supply of manpower to do research must be insured.
More co-ordination of research at the national level, more consistent policy, and more planning are needed; this applies to the amount and kinds of research desired, and also to the amount and kinds of research manpower desired.
More support is needed for graduate studies.
More money in general is needed for research; there should be more basic research.
The public has a negative attitude toward science and technology.
Government (State, local, or Federal) or one of its branches or agencies has a negative attitude toward science and technology.
Funds are needed for research equipment, instrumentation, and maintenance.
Increased teaching loads take time away from research.
More support for university research should be supplied at the institutional level.
A program of education or communication is needed to convince the public and government of the value of research.
Problems peculiar to the individual research disciplines are mentioned.
There are excessive demands for accountability in the use of funds provided by government.
There is the threat of legislative interference in the making of grants and the choice of research areas or in the organization of the research effort.
Other needs for funds (e.g., seed money for new research ventures).
Enrollments in science are declining; graduate students are less capable currently than they used to be.
Problem areas are suggested in which research would benefit the public.
General problems of faculty—in particular, morale; more money is needed to pay faculty.
Regulations are imposed by government, in order to enforce certain public policies, that are excessive or irrelevant to the conduct of research and therefore hinder it.
The peer-review system must be maintained.
More interdisciplinary research is needed; organizations should be set up for it.
It is difficult to keep up the vitality of a department's research effort with fewer graduate students and young faculty.
New Ph.D.'s cannot find jobs.
Distribution of funds should be based on size or reputed quality of institutions, not on geographical balance.
More support is needed for postdoctoral studies.
Competition with other research sectors is undesirable and should be minimized.
More funds are needed to pay support personnel on research projects.
Specialized research institutes should be set up in certain research areas.
Universities must adapt themselves to the new economic situation.
The grant-making process is slow and wastes the researchers' time.
In general, there is overregulation of research by government.
Distribution of funds should be based on geographical balance, not on the size or reputed quality of institutions.
Research support at the institutional level is undesirable.
Interdisciplinary research is being overdone.

Table D-2.—Complete List of Issues Taken from Industry Sector

Government regulations and controls (unreasonable, not thought out, no cost/benefit/risk analysis).
Absence of national science and technology policy, priorities or goals.
Near-term relevance is only research objective (due to government regulations or decentralization of research to profit centers).
General economic conditions, particularly inflation in salaries and laboratory costs, lead to decreases in fundamental research in industry.
Low public confidence in and/or poor image of science, technology, research or scientists.
Lack of availability of money, low profitability or obstacles to capital formation lead to decreases in fundamental research in industry.
Concern over general decrease in fundamental and other research in industry.
Deteriorating patent protection or patent policy is a disincentive to industrial research and innovation.
Too few/too many scientific and technical personnel—no match with need—lack of national policy on scientific and technical personnel.
Competing R&D functions (e.g., applied research or development in response to government regulations) decrease fundamental research in industry.
Concern about quality of new people—best are not entering science and engineering or, if they do, are kept for university .
Concern whether other sectors will compensate for decrease in industrial fundamental research.
Fundamental research in industry has become too risky and has reduced future payoff.
Concern over Federal pressures for shift to short-term and/or applied research.
Need for planning and continuity for science and technology at national level.
Lack of long-term capital and low profits result in shifts from more basic to short-term and/or applied research.
Lack of recognition of relationships among basic research, applied research, development and innovation contributes to shift to short-term and/or applied research.
Concern over low public confidence in and poor image of industrial corporations.
Anti-trust and licensing regulations and other barriers to research and innovation.
Need for coordination of research performers from all sectors.
General social climate including attitudes towards business, profits and science is not conducive to fundamental research in industry.
Random and illogical consumer "attacks" on products and practices do not favor long term deployment of personnel in basic research.
Failure of public to recognize role of large corporations in innovation.
Government acts as adversary to industry.
Technological obsolescence.

Table D-3.—Complete List of Issues Taken from Government Sector

Need for co-ordinated research policy at the national level involving long-range planning, commitments and priorities.
Increased emphasis on short-term research and neglect of basic research.
Overmanagement as evidenced by too many restrictions, especially on longer term research.
Need for increased or stable funding.
Desire for improved personnel management (e.g., personnel changes, salary scales, staff levels, etc.).
Need to maintain research staff vitality with more positions for young scientists and continuing education for older ones.
Meeting public demand for justification of basic research programs with respect to mission.
Lack of Congressional or Executive support and understanding of basic research.
Balance between role of public and role of scientist in choosing applications of technology.
Fear that science has become unattractive as a career.
More funds needed for scientific equipment.
Need for more interaction between government laboratories.
Need for more interaction between government sector and other research sectors.
Concern over decrease in the amount of "in-house" research.
Need for improved general management skills.

Table D-4.—Complete List of Issues Taken from Independent Research Institutes

Need for long-term continuity in funding.
Lack of coherent national science policy especially toward IRI's.
Need for adequate justification of research.
Manpower needs—particularly in IRI's—as problems associated with multi-disciplinary efforts.
Federal pressure toward over-direction of research with emphasis on short-term or applied research.
Need for research funds including construction funds.
Overemphasis on short-term or applied research.
Is the applied research-basic research distinction useful in explaining research?
Problems about preferential distribution of research funds to other sectors.
Need for continuing assessment of research quality at all institutions by means of peer review.
Time to establish national priorities and associated research needs.
Adverse effects of government regulations on research output (e.g., rulings on tax status, excessive accountability, etc.).

Appendix E
RANK-ORDER TABLES OF ISSUES MENTIONED MOST FREQUENTLY

This appendix contains four tables, each listing the issues reported most frequently by one of the sectors. On each table there are also columns representing different classes of respondents in that sector. The numbers in the columns represent the prominence that that class of respondents gave to each issue; "1" stands for the issue most frequently mentioned by that class of respondents in that sector, etc. In some cases, a column shows the same number for more than one issue. This indicates that all issues assigned the same number were mentioned with the same frequency. When a number is duplicated in a column, the next higher number does not appear.

The numbers so assigned are the rank-orders of each issue with respect to each class of respondents. Some columns represent various combined classes of respondents, and each sector has a column that represents all respondents from that sector combined.

In some columns only a few issues are given rank orders, while other columns assign numbers to many more issues. The general rule for this, outside the university sector, was to assign a rank order to each issue whose frequency was at least a third of the frequency of the first-ranked issue in that column. This rule was modified in the case of columns representing relatively small groups of respondents, in which the cut-off was one half the frequency of the first-ranked issue. The rule was also modified slightly to leave a fairly large gap, when possible, between frequencies of the issues that were numbered and those that were not.

A simpler rule was used in the university sector. There, each column shows the eight issues mentioned most frequently by each class of respondent. The exception was the mathematical sciences, where there were not enough respondents to allow eight significant issues to be distinguished.

In the university sector, the respondents are divided according to their title and the Carnegie Research University classification of their institution. In addition, the department chairmen are classified according to the academic disciplines that they represent. Five broad classifications are used: engineering, mathematical sciences, physical sciences, life sciences, and social and behavioral sciences. All the responding chairmen's departments were classified under these headings, with the aid of the Final Department Code Book of the 1974 Graduate Science Student Support and Postdoctoral Survey. This is a listing of names of university departments that has been used for many years by the NSF's Division of Science Resources Studies.

Many observations can be made about the different interests of the different classes of university respondents. For example, the presidents and the vice presidents for research seem to have had much the same interests, except that vice presidents were more concerned about the supply of research manpower. However, there are major differences between Research Universities I and II. The latter expressed a relatively high interest in institutional support, but a low interest in national coordination and planning. The Universities II also seem to have been more concerned about governmental and public attitudes toward science.

Chairmen showed a lower interest in national planning, institutional support, or governmental and public attitudes. Rather, they were concerned about the problems relating to tenure and opportunities for younger faculty, as well as obtaining money for graduate education, and problems of their individual fields. Chairmen at Universities I expressed more interest in maintaining the supply of research manpower than did those at Universities II. At the same time, the latter were more interested in the

Table E-1.—Leading Issues as Reported by University Respondents

Statement of Issue (Abbreviated)	All Respondents	All Presidents and Vice Presidents	Carnegie I Pres. and Vice Pres.	Carnegie II Pres. and Vice Pres.	All Presidents	All Vice Presidents for Research
	Order of Frequency of Mention by					
Pressure for applied, overly targeted, rather than basic research	1	1	1	1	1	1
Need for more continuity and stability of funding, longer grants ...	2	2	2	4	2	2
Problems of younger faculty, tenure problems	3			7		
Continued supply of research manpower must be insured	4	4	4	6	7	2
Need for more national coordination of research, more consistent planning	5	3	3		3	4
Support needed for graduate program	6			7		
More research money or more basic research needed	7	8	6		7	7
Public has negative attitude toward science and technology ..	8	5	8	3	4	6
Government has negative attitude toward science and technology ..		6	7	4	4	7
Funds needed for research equipment						
Teaching and other duties take time from research						
More research support needed at institutional level		6		1	6	5
Problems of individual fields						
Excessive demands by government for accountability			5			
Fewer or less capable graduate students						
Areas for applied research suggested						
Number of respondents counted	425	147	81	66	75	72

pressures that teaching and administrative loads put upon the research effort and in proposing practical areas in which research is needed.

Among the departments, engineering was relatively quite unconcerned about pressures to do applied rather than basic research. Interest in the future supply of research manpower was greatest among those in the physical and life sciences. Respondents in the mathematical and life sciences were most concerned about public attitudes. Engineers were most concerned about a need for more money or more basic research. Social and behavioral scientists

	All Department Chairmen	Carnegie I Chairmen	Carnegie II Chairmen	Engineering Chairmen	Mathematical Sciences Chairmen	Physical Sciences Chairmen	Life Sciences Chairmen	Social and Behav. Sci. Chairmen
	1	1	1	7	3	1	1	2
	2	3	2	1		3	3	3
	3	2	3	3	1	2	2	7
	4	4		7		4	4	
	8	6				7	6	
	5	5	6	2		5	6	8
	7	7		3				5
					3		5	
						6		
			4				8	4
	6	7	8		1			1
			6	6		8		
			4	3				5
	278	167	111	56	13	88	59	62

showed the least interest in the problems of young faculty and tenure. Engineers had the greatest interest in the availability of funds for graduate programs. Mathematical scientists (who were not very numerous among our respondents) and social scientists were the ones who most often expressed concerns about their individual fields. In the latter case, these often had to do with a perceived need for long-term projects to collect and store data. Engineers and social scientists most often suggested application areas for research. Social scientists were especially concerned about pressures placed on research by the rest of the education program.

Table E-2.—Leading Issues as Reported by Industry Respondents

	Order of Frequency of Mention by		
	All Respond-ents	Presidents	Vice Pres. and Dirs. of R&D
Government regulations and controls (unreasonable, not thought out, no cost/benefit/risk analysis)	1	1	1
Absence of national science and technology policy, priorities or goals	2	2	4
Near-term relevance is only research objective (due to government regulations or decentralization of research to profit centers)	3		2
General economic conditions, particularly inflation in salaries and laboratory costs, lead to decreases in fundamental research in industry	4	3	5
Low public confidence in and/or poor image of science, technology, research or scientists	4	6	3
Lack of availability of money, low profitability or obstacles to capital formation lead to decreases in fundamental research in industry	6	4	8
Concern over general decrease in fundamental and other research in industry	6	5	7
Deteriorating patent protection or patent policy is a disincentive to industrial research and innovation	8		5
Too few/too many scientific and technical personnel—no match with need—lack of national policy on scientific and technical personnel	9		8
Competing R&D functions (e.g., applied research or development in response to government regulations) decrease fundamental research in industry	10		10
Concern about quality of new people—best are not entering science and engineering or, if they do, are kept for university	10		10
Concern whether other sectors will compensate for decrease in industrial fundamental research			10
Fundamental research in industry has become too risky and has reduced future payoff			10
Concern over low public confidence in and poor image of industrial corporations		6	
Number of Respondents	123	45	78

Table E-3.—Leading Issues as Reported by Government and FFRDC Respondents

	Order of Frequency of Mention by			
	All Re-spond-ents	Intra-mural Labor-atory Directors	Federal Head-quarters Officials	FFRDC Labor-atory Directors
Need for co-ordinated research policy at the national level involving long-range planning, commitments and priorities	1	2	3	1
Increased emphasis on short-term research and neglect of basic research	2	1	1	3
Overmanagement, as evidenced by too many restrictions, especially on longer term research	3	5	3	2
Need for increased or stable funding	4		3	4
Desire for improved personnel management (e.g., personnel changes, salary scales, staff levels, etc.)	5	2	3	
Need to maintain research staff vitality with more positions for young scientists and continuing education for older ones	6	6	1	
Meeting public demand for justification of basic research programs with respect to mission	7	4		
Lack of Congressional or Executive support and understanding of basic research	7	6		
More funds needed for scientific equipment			3	
Need for improved general management skills			3	
Number of Respondents	55	25	8	22

Table E-4.—Leading Issues as Reported by Respondents from Independent Research Institutes

	Order of Frequency of Mention by Presidents and/or Directors
Need for long-term continuity in funding	1
Lack of coherent national science policy especially toward IRI's	2
Need for an adequate justification of research	2
Manpower needs—particularly in IRI's—as problems associated with multi-disciplinary efforts	4
Federal pressure toward over-direction of research with emphasis on short-term or applied research	5
Need for research funds including construction funds	5
Overemphasis on short-term or applied research	7
Is the applied research-basic research distinction useful in explaining research?	7
Number of Respondents	21

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NATIONAL SCIENCE FOUNDATION

WASHINGTON, D.C. 20550

October 5, 1976
PA/M (76-31)

MEMORANDUM TO SCIENCE WRITERS AND EDITORS

Subject: Eighth Report of the National Science Board, Science at the Bicentennial--A Report from the Research Community

The President has transmitted to the Congress the eighth annual report of the National Science Board (NSB). The report, Science at the Bicentennial--A Report from the Research Community, was prepared by the NSB, policy-making body of the National Science Foundation. Dr. Norman Hackerman, President of Rice University, is Chairman of the NSB.

The main body of the report is made up from comments by several hundred representatives of the research community in the United States on existing and prospective problems in research operations.

Their comments, made in response to letters of inquiry from NSB, showed the greatest concerns to be in these areas:

--Dependability in funding for research.
--Vitality of the research system.
--Freedom in the research system.
--Confidence in science and technology.

Also included in the report are a chapter providing some historical perspective on research in the United States and a study of available surveys on public attitudes toward science and technology (Part II of Chapter 6).

In transmitting the report to the President, Dr. Hackerman said: "The National Science Board believes the report points to a need for action in which government, the scientific community, and the public have a part, to assure that these concerns are properly addressed."

The letters of inquiry were addressed by the Board to persons active in the four principal sectors of research: the universities, industry, Government, and independent research institutes.

The report concentrates on the circumstances which might affect the capacity of the Nation to continue a strong position in science and technology. The Board's inquiry sought to identify selected critical problems developing in the four sectors. Addressees were asked to describe the two most critical issues or problems they were encountering or anticipated which will influence the productivity of working scientists and engineers and will decrease the effectiveness of research unless properly addressed.

The report is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Price: $2.95 Stock Number: 038-000-00280-5.

Jack Renirie

Jack Renirie
Head, Public Information Branch

FOR IMMEDIATE RELEASE OCTOBER 1, 1976

Office of the White House Press Secretary

THE WHITE HOUSE

TO THE CONGRESS OF THE UNITED STATES:

I am pleased to submit to the Congress the eighth annual report of the National Science Board, Science at the Bicentennial -- A Report from the Research Community.

This report reviews the history of research in the United States and summarizes the results of a survey conducted by the Board in 1975 which sought the opinions of research managers on the problems facing basic research in universities, industry, Federal laboratories and nonprofit institutes.

The report reflects the pride of the research community in the tremendous accomplishments resulting from the scientific research effort in the United States, particularly since World War II. The report shows concern about a number of problems facing research institutions in 1975. It also shows the expectations for many more contributions in the future from science -- contributions which will be important to the strength and well-being of our Nation.

The thoughtful statements expressed in this report will receive the attention of my new Office of Science and Technology Policy and the new President's Committee on Science and Technology, which will soon begin its two-year examination of the overall context of the Federal science, engineering and technology effort.

The strength and prosperity of the United States which is so respected throughout the world is due in large measure to the contributions of scientific research. I believe this force must be maintained and I have sought significant increases in Federal funding for basic research in my 1977 Budget, in fact, an increase of 11 percent over 1976 estimates. This increased funding would reverse the decline in the levels of Federal support for basic research that began in 1967.

The views set forth in this report will enhance our ability to make informed decisions about the Nation's support of science. I commend it to the attention of the Congress.

GERALD R. FORD

THE WHITE HOUSE,
OCTOBER 1, 1976