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Selecting Research Institutions for the Performance of Public Science Activities: Criteria for Institutional Choice in National Minerals Research Programs

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Title SELECTING RESEARCH INSTITUTIONS FOR THE PERFORMANCE OF PUBLIC SCIENCE ACTIVITIES: CRITERIA FOR INSTITUTIONAL CHOICE IN NATIONAL MINERALS RESEARCH PROGRAMS

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SELECTING RESEARCH INSTITUTIONS FOR THE PERFORMANCE OF PUBLIC SCIENCE ACTIVITIES: CRITERIA FOR INSTITUTIONAL CHOICE IN NATIONAL MINERALS RESEARCH PROGRAMS

BY
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THESIS

Submitted in Partial Fulfillment of the
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ABSTRACT OF THESIS

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ABSTRACT

A large scale technological effort is required to insure that the nation has a dependable supply of critical minerals and fuels at socially and economically acceptable costs. The required level of technological effort implies governmental programs and the selection of institutions for the performance of research and development. The choice of institutions has profound implications for social, political, and economic structures; therefore, such choices must be carefully based on relevant criteria. Institutional criteria have not been heretofore developed in any comprehensive, analytical framework.

A. STRUCTURE, DESIGN, AND OBJECTIVES OF THE THESIS

The thesis addresses the question of the most suitable institutional arrangements which will best meet the national interest in the area of mineral resource development and technology. The challenges and requirements of the minerals sector are examined. Then the institutional practices of national research programs are investigated. These investigations lead to the development of criteria for institutional choice which are then applied to the particular features of the minerals sector. Alternative institutional possibilities are discussed, leading to specific recommendations for a national mineral resource development institution.

B. THE CHALLENGES AND REQUIREMENTS OF THE MINERALS SECTOR.

The principal challenge is keeping the real cost of minerals on a declining curve in the face of rapidly accelerating demand and decreasing

supplies of high grade deposits and reservoirs. The need for environmental protection and pollution control complicates the problem. Technology is required to meet these challenges; however, the minerals sector is poorly equipped to provide the required technological effort. Minerals education is in decline. The minerals industry is relatively fragmented and not research intensive. There is no national policy on mining and minerals. Governmental efforts in minerals technology are relatively small and poorly coordinated.

C. IMPLICATIONS OF INSTITUTIONAL CHOICE

Since 1940, federal managers have utilized a bewildering array of institutional mechanisms for the accomplishment of public science programs. Institutional means have been bent to program ends. Results of this practice have included the intertwining of public and private enterprise, raising issues of governmental accountability and responsibility. Patterns of new federalism have developed which have reshaped the American political society. Criteria of institutional choice have not existed in any comprehensive framework, nor have their implications been analyzed.

D. CRITERIA FOR INSTITUTIONAL CHOICE

Twenty-five criteria are identified, discussed, and analyzed in relationship to institutional alternatives. These criteria are arranged in eight general categories as follows: Nature of the R&D Program; Merit of the R&D Program; Public and Private Interest; Efficiency and Effectiveness; Governmental Responsibility; Participation and Representation; Educational Considerations; and Technology Transfer and Past Practice.

E. INSTITUTIONS FOR MINERALS RESEARCH

Application of criteria of institutional choice to the problems of the minerals sector leads to the recommendation of the establishment of a National Institute of Minerals Research and Development (NIMRAD). This institution is designed to serve as a focal point for the revitalization and mobilization of technological effort in industry, education, and government. NIMRAD will also serve to translate national minerals policy into effective action.

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PREFACE

The issues involved in the interrelationships of mineral resources and public policy are as old as civilized man. The major issues created in the United States by the choice of institutions to perform national research and development programs are less than thirty years old. The intent of this study is to examine these issues and to achieve something of a synthesis in the form of analysis and recommendations of institutional choice for the conduct of the nation's minerals research programs.

The inception of the study goes back to 1966 when the U. S. Bureau of Mines asked for and received authorization to contract-out research and development. After a half century of pure in-house research effort, the Bureau faced new questions and new problems. For two years after 1966, I was counted among those who believed strongly that in-house operations provided the only legitimate, straightforward, acceptable way of performing government research programs. This belief stemmed from some personal resentment on the part of a government employee at the higher wages that government contractors could pay their employees out of government funds -- higher wages than we civil servants could command for similar work also paid out of government funds. Professionally, as a personnel specialist, my reluctance to accept contracting-out stemmed from the prospect of providing contractors with the resources with which they could effectively compete with the government for required technological manpower. My reservations on these two points still stand, but other considerations have come to the fore.

The opportunity for further reflection, study, and investigation of these and related issues was made possible when the Bureau of Mines encouraged and supported me in a course of full-time study. The other essential aspect of the opportunity was the existence of the newly established Program for Advanced Study in Public Science Policy and Administration at the University of New Mexico. The resources of the Program, supported by NASA and developed by Dr. Albert Rosenthal, have provided the means and framework for this study. The counsel of Dr. Rosenthal, Dr. John Hunger, and Dr. Lloyd Woodruff have materially furthered the study.

I must also express my deep appreciation and debt to all sixteen of my colleagues in the first PASPSPA program. Their constructive advice, sharing of experiences, and friendly competition have contributed significantly. The influences of faculty and colleagues have encouraged a staff administrative specialist to embark on a study of the complex interface between technology, society, and public policy in a significant sector of our economy. The merits and strengths of this study are due in large measure to the aforementioned. Any shortcomings, omissions, and errors of interpretation are my own.

CHAPTER I

MINERALS TECHNOLOGY, PUBLIC POLICY, AND INSTITUTIONAL CHOICE: AN OVERVIEW

The Malthusian statement of the problem of mineral resources is forthright: As the finite supply of minerals becomes depleted and as utilization rapidly increases, we face an inevitable crisis of shortage of the basic material elements of our industrial society. As with other dire Malthusian predictions, this one has been disproven or at least deferred by rapid advances in the technologies of minerals exploration, extraction, processing, and utilization. The technological advances have been great enough to meet tremendous increases in minerals demand in the last century. The question remains, however, whether technology will be able to meet the future challenges of even greater demand, of shrinking resources, and of pressure toward rising real costs, not only in the United States and other developed economies but also in the rest of the fast developing world.[1]

While the harsh doctrine of scarcity has perhaps been alleviated by technology, the issue has shifted to concerns of cost. Resource economists today view scarcity as not physical but as cost-relevant. As one leading economist has stated:

> While this new viewpoint modifies the problem of scarcity, it by no means solves it. If the costs of obtaining scarce natural resource products, or of developing substitutes for them, should rise significantly in relation to other costs, society would be devoting larger shares of manpower and capital to their production. At best, rising real cost would be a drag on the continued improvement in average levels of living; it could halt, or even reverse, the upward trend of recent decades.[2]

Still, the conventional solution is viewed as one of advancing technology, now addressed to cost factors as well as problems of resource availability.

The role of science in natural resource development is highly significant. President John F. Kennedy noted this emphatically in 1963 as the first item on his technological agenda: "This seems to me the greatest challenge to science of our times, to use the world's resources, to expand life and hope for the world's inhabitants. While these are essentially applied problems, they require guidance and support from basic science."[3]

The concern of government today about the technological problems of minerals is well stated by Interior Secretary Walter J. Hickel:

> With respect to the Nation's long-range mineral position, we believe the United States has cause for deep concern. It is our considered opinion that unless an urgent effort to up-grade minerals and mining technology is launched soon, we face the possibility that the growth in our standard of living will be limited due to mineral resource constraints within 20 to 30 years.[4]

In his challenging book, The Age of Discontinuity, Peter F. Drucker sees four new industries on the horizon which will shape the future of our social economy. One of these is the materials industry, implying the advent of a new materials technology.[5] But new technologies create new kinds of problems. As technology has transformed atoms and molecules into the basic building blocks of natural resources, in place of ores and mineral deposits, we face new social problems and new opportunities for choice among ever-widening alternatives.[6]

The technology of mineral resource extraction, processing, and utilization has been heavily responsible for the scarring of our land and the pollution of our environment. Suddenly, the quality of our environment has become one of the primary political issues of our time. The scarcity and cost aspects of the minerals problem have been joined by the environmental issue. The question becomes one of how we can enjoy the benefits of an industrial society and an affluent economy, resting on the base of minerals extraction and utilization, without destroying our environment. If this is not possible, then what materials and substances can we use instead of minerals?

Again, the conventional solution is advancing technology to cope with the environmental problems of the minerals sector. But the conventional wisdom is no longer accepted uncritically. Former Interior Secretary Stewart Udall was an early critic of what he termed "the myth of scientific supremacy" and the general "let-science-fix-it-tomorrow attitude."[7] In fact, to many, technology has clearly become more a cause of the problem than a potential solution to it.

Another alternative to advancing technology has presented itself in the form of what Kenneth Boulding calls the spaceship economy, indicating a change on earth from: "an open society characterized by a throughput of material (with ores and fossil fuels as inputs and pollutable reservoirs as recipients of outputs), to a closed society in the material sense, in which there are no longer any mines or pollutable reservoirs, and in which therefore all material has to be recycled."[8] Boulding is joined by John Kenneth Galbraith in advocating a low- or no-growth economy, extreme conservation, and restricted consumption as means of correcting our industrially created environmental problems.[9]

It is difficult to believe that a society such as ours, so inculcated with the values of growth and progress, could accept a non-growth, restricted consumption economy. We tend to be action oriented, which again raises the necessity of searching for technological solutions to pressing problems. But the search must embrace more than naked technology. Our modern natural resource problem involves a broad social adjustment to the adverse effects of technological change and economic growth.[10] Barnett and Morse phrase it succinctly: "The capacity of scientific progress to create new problems for society, it appears, has outrun the capacity of social progress to solve them."[11] In terms of governmental action programs to meet the challenges of our time, it would seem that new institutions and new political theory are needed.

One authority has stated that the "professionalization of science during the nineteenth century rested upon the building of new institutional forms for science education."[12] Perhaps we may state that the legitimization of science in the governmental context is now also dependent on the development of new institutional forms. A profuse variety of new forms have in fact developed, but not in any coherent or systematic way, during the great leap of science to public prominence in the last thirty years. The effects of the institutional choices made during those years have not truly been assessed.

The genius of our political system lies in part in its institutional arrangements. The design of such arrangements is no less important in regularizing and legitimizing the place of technology in the arena of public policy. In a recent discussion, C. West Churchman stated that the most pressing problems of the future may well be questions of decentralization, not technology. In short: "How do we get more people in the act?"[13]

In some ways more people are already getting into the act. One of the most striking features of American life in the latter half of the twentieth century has been the development of intimate interrelationships between government, industry, and the academic world in areas of advanced technology. This phenomenon has taken on the aspect of a closed system, raising the question of representation of a broader public interest. Most recently, in our stubbornly pluralistic society, questions of technology have been dragged into the arena of public debate. Questions of minerals technology and its relationship to the economy and the environment are sure to become increasingly important topics of political discussion.

The choice of institutions for the conduct of public research and development programs in the past has had profound implications for our social, political, and economic structures. There is no reason to believe that future choices will be any less significant. Consequently, we must choose carefully and develop institutional arrangements with an acute sensitivity to the issues involved.

We come then finally to the objectives and structure of this study. Quite simply, we are addressing the question of the most suitable institutional arrangements which will best meet the national interest in the area of mineral resource development and technology. We first look closely at the challenges and requirements of the minerals sector. Then we investigate the institutional practices of national research programs. These investigations lead to the development of criteria for institutional choice. We then apply the criteria to the particular features of the minerals sector, discuss alternative institutional possibilities, and arrive at specific recommendations for a national mineral resource development institution which will serve the public interest.

FOOTNOTES for CHAPTER I

1. U. S., The President's Materials Policy Commission, Resources for Freedom: Summary of Volume I of a Report to the President (Washington: U. S. Government Printing Office, 1952), pp. 1-2.

2. Hans H. Landsberg, Natural Resources for U. S. Growth: A Look Ahead to the Year 2000 (Baltimore: The Johns Hopkins Press, 1964), p. 3.

3. John F. Kennedy, "Research, Technology, and Public Policy," Physics Today, XVI (December, 1963), 24. This was the President's address to the National Academy of Sciences, October 22, 1963.

4. U. S., Congress, Senate, Committee on Interior and Insular Affairs, National Mining and Minerals Policy. Hearing before the Subcommittee on Minerals, Materials, and Fuels on S. 719, A Bill to Establish a National Mining and Minerals Policy, 91st Cong., 1st Sess., 1969, p. 2.

5. Peter F. Drucker, The Age of Discontinuity: Guidelines to Our Changing Society (New York: Harper and Row, 1968), pp. 29-33.

6. Harold J. Barnett and Chandler Morse, Scarcity and Growth: The Economics of Natural Resource Availability (Baltimore: The Johns Hopkins Press, 1963), pp. 238, 244.

7. Quoted in Walter R. Hibbard, Jr., "Mineral Resources: Challenge or Threat," Science, CLX (April 12, 1968), 143.

8. Kenneth E. Boulding, "The Great Society in a Small World: Dampening Reflections from the Dismal Science," in Bertram M. Gross, A Great Society? (New York: Basic Books, 1966), p. 219.

9. John Kenneth Galbraith, "How Much Should a Country Consume?" in Readings in Resource Management and Conservation, ed. by Ian Burton and Robert W. Kates (Chicago: University of Chicago Press, 1965), pp. 261-267. Also see John Kenneth Galbraith, "To My New Friends in the Affluent Society--Greetings," Life, LXVIII (March 27, 1970), 20.

10. Barnett and Morse, Scarcity and Growth, p. 258.

11. Ibid., p. 262.

12. Everett Mendelsohn, "Three Scientific Revolutions," in Science and Policy Issues: Lectures in Government and Science, ed. by Paul J. Piccard (Itasca, Ill.: F. E. Peacock Publishers, Inc., 1969), p. 32.

13. C. West Churchman, discussion held at Albuquerque, New Mexico, January 7, 1970.

CHAPTER II

THE CHALLENGES AND REQUIREMENTS OF THE MINERALS SECTOR

From time to time during the last century, alarm has been voiced concerning the state of the minerals industry. Conventionally, the alarm has concerned the declining fortunes of mining interests, the inevitable depletion of natural mineral and fuel resources, and the decline of minerals education. An early example of this kind of concern is found in J. Ross Browne's report on western mineral resources in 1868: "No country in the world can show such wasteful systems of mining as prevail in ours. . . . The question arises whether it is not the duty of government to prevent, as far as may be consistent with individual rights, this waste of a common heritage, in which not only ourselves but our posterity are interested."[1] Browne was advocating passage of a bill sponsored by Senator Stewart of Nevada to establish a National School of Mines to be located in the mining region, operated by a Board of Directors composed of representatives of each mining state, with the primary objective of applying science to mining.[2]

Senator Stewart's enlightened bill failed of passage. We do not have to this day a National School of Mines; we hardly have any schools of mines of any description left in the United States. And the alarms have continued. In 1952, the President's Materials Policy Commission (Paley Commission) issued a five volume review of the national resources situation, and each volume expressed deep concern over some aspect of mineral resources.[3] In 1963 the Senate conducted hearings entitled State of the Minerals Industry which again called attention to the serious problems facing the nation in regard to its minerals position.[4] In 1969 the Senate again conducted hearings, this time on legislation proposed by Senator Allott to establish a national mining and minerals policy.[5] Again, deep concern was voiced by a broad range of witnesses regarding the seriousness of the national minerals situation.

These periodic alarms have not resulted in any coordinated action to create solutions to well-understood problems. While minerals have long been recognized as essential to the nation, they have not become the subject of a coherent, forceful public policy. Senator Allott's modest proposal for the declaration of a national policy, which he has been advocating for many years, has met the same fate of Senator Stewart's bill a hundred years earlier.

Since World War II the nation has supported, encouraged, and fostered great technological advances in atomic energy, weapons, space, and health. But little has been done about minerals problems. The budget and sphere of activities of the U. S. Bureau of Mines, the principal organization charged with national minerals responsibility, have remained relatively static. The failure of the nation to give substantial support to minerals technology continues as the economic problems posed by minerals become increasingly critical.

A. FUNDAMENTAL PROBLEMS FACING THE MINERALS SECTOR

The economic welfare of the nation is heavily dependent on keeping the real cost of minerals and fuels on a declining curve. Attainment of this objective is becoming increasingly difficult. The extraction, processing, and utilization of minerals are becoming increasingly costly. The rich and easily recoverable ores are already mined. We must now mine deeper and look to more remote regions for our domestic mineral resources. We are becoming increasingly reliant on foreign sources of mineral supply. In addition, conservation and anti-pollution measures and stricter health and safety standards in the mineral industries are adding to the cost of producing needed materials. Finally, the production of trained manpower to attack the tangible problems is at a low ebb. The educational lag leads inevitably to technological lags and to a further deterioration of our minerals position.

A primary problem facing the minerals sector is the rapidly accelerating demand for the mineral raw materials which form the basic building blocks of our industrial economy. The extraction of minerals accounts for only about three percent of the U. S. gross national product, but these minerals represent the essential economic multipliers in industrial production comprising seventy-five percent of the gross national product. In the past century, while U. S. population has grown 400 percent, minerals consumption has grown more than 4,000 percent.[6] Future projections show continued rapid increase in minerals demand. For example, we have indications of "a tripling of requirements for both energy and metals" by the year 2000.[7] Figure 1 indicates the substantial nature of the demand problem.

Coupled with increasing demand is the problem of decreasing supplies of readily accessible and rich ores, deposits, and reservoirs. The easily recoverable minerals have long ago been recovered.[8] We are

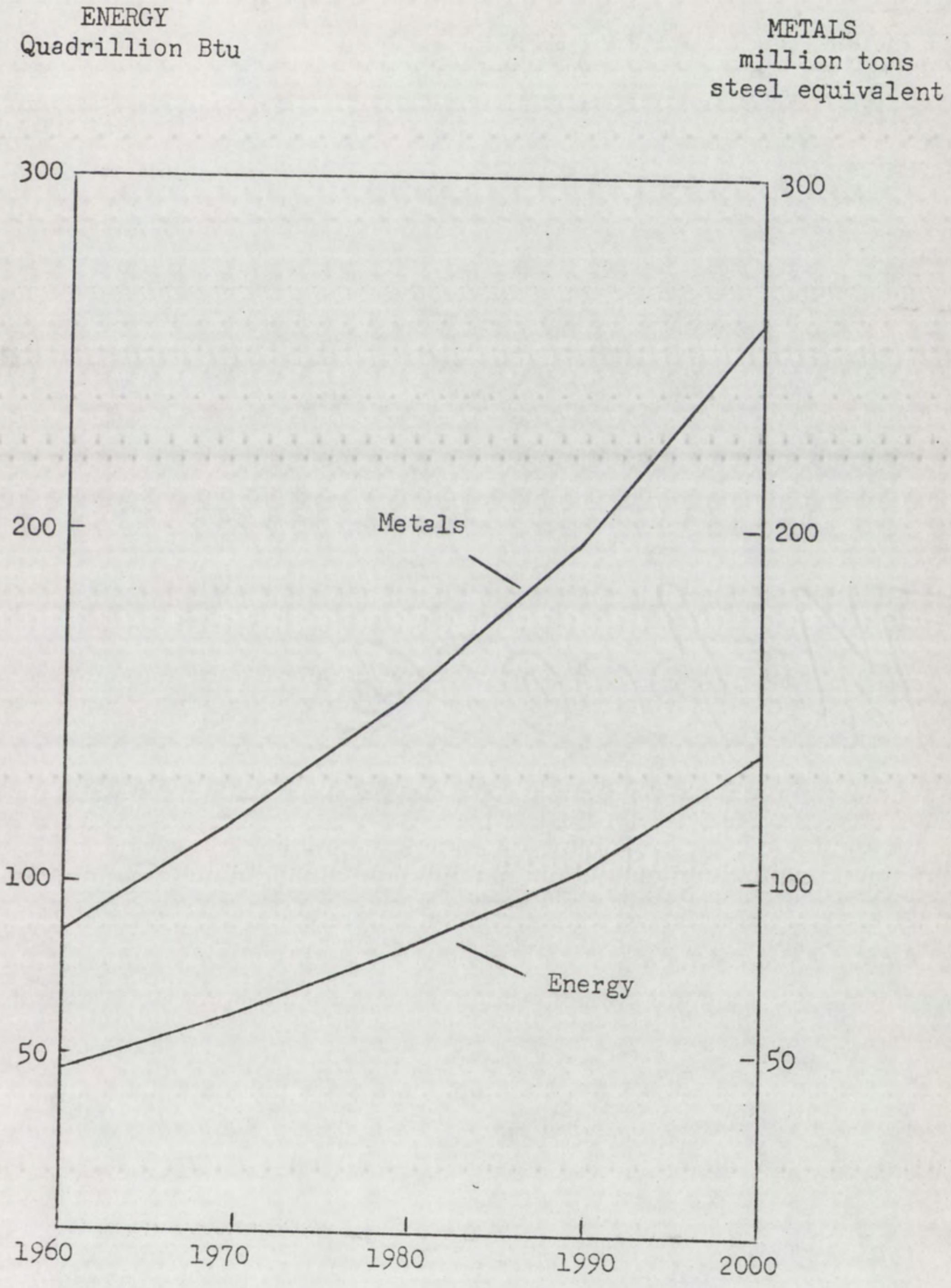


Figure 1. Growing U. S. Needs for Mineral Resources.

Source: Hans H. Landsberg, Natural Resources for U. S. Growth: A Look Ahead to the Year 2000 (Baltimore: The Johns Hopkins Press, 1964), p. 12.

left with the necessity of utilizing lower grade resources. There is no shortage of low grade resources, but their utilization implies the possibility of increasing costs. Over the years, the application of technology has resulted in declining real costs for minerals, despite the accelerating demand and the need to utilize lower and lower grade resources.[9] However, the declining curve for mineral costs is no longer a fact, and we suspect in many commodities that the cost curve is beginning to rise.[10] The implications of rising costs are substantial, affecting not only the minerals producers, but also the fabricators and ultimately the consumers.

An additional problem in the economics of mineral resources is our increasing reliance on imports for our critically needed materials. The U. S., once a resource exporting nation, is now heavily a resource importer. This is a result both of rising demand and declining domestic production.[11] Figure 2 illustrates the trend toward increasing imports, and the trend is expected to accelerate rapidly in the future. Reliance on foreign minerals has many implications including problems of security of supply, dependence on others, unfavorable trade balances, declining domestic industries, and the certainty that developing nations will one day require their own minerals for their own uses.

Finally, a new national insistence on environmental protection is affecting the economics of the minerals sector. The effects are clearly calculable in terms of costs. For example, the costs of minerals extraction, processing, and utilization are increased if the air pollution ingredients of coal must be removed as it is consumed to produce electricity, if mine scarred lands must be restored for recreational

VALUE OF U. S. MINERAL IMPORTS AS PERCENT

OF DOMESTIC PRODUCTION

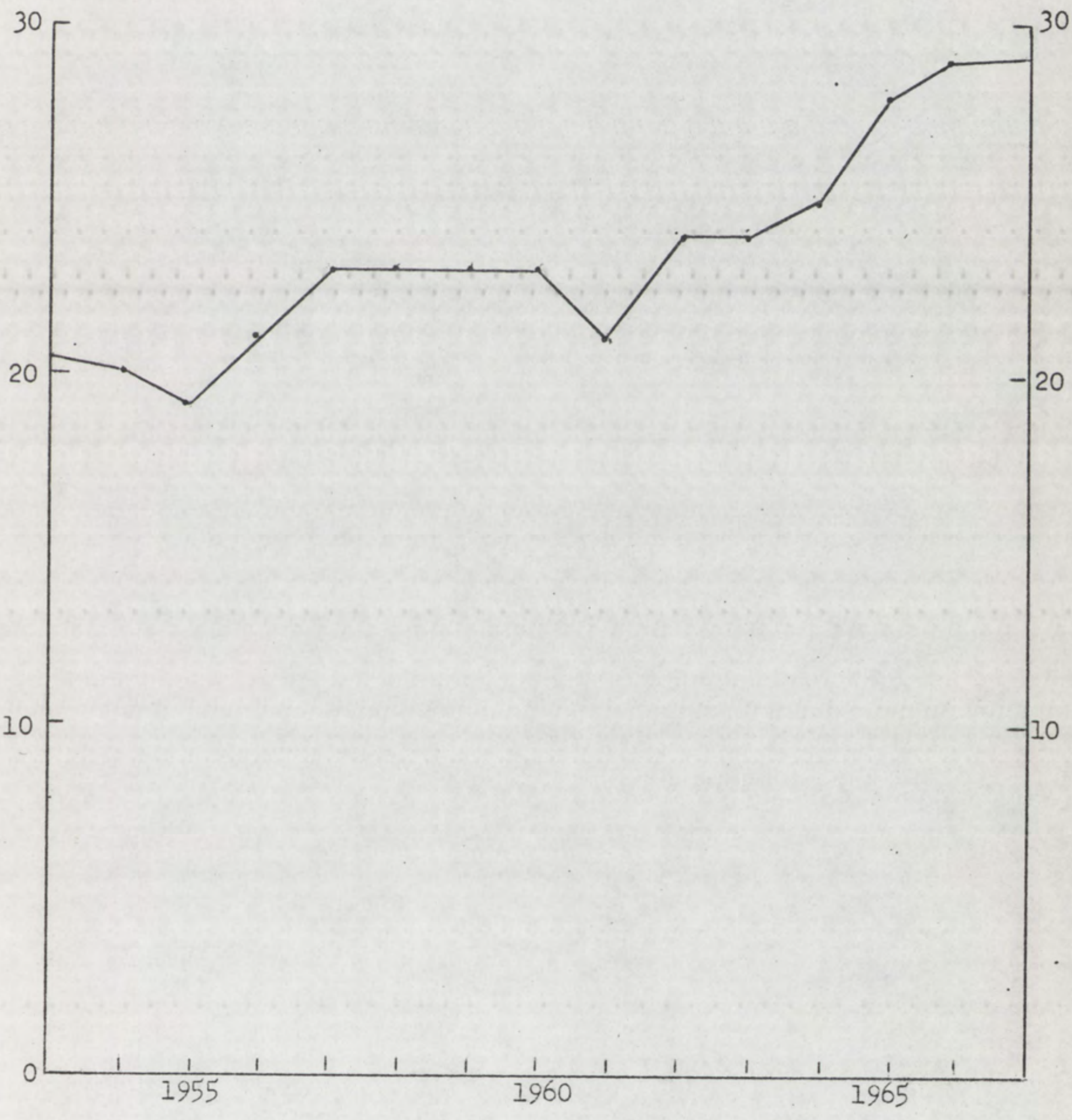


Figure 2. Value of U. S. Mineral Imports as Percent of Domestic Production.

Source: U. S., Congress, Senate, Committee on Interior and Insular Affairs, National Mining and Minerals Policy, 91st Cong., 1st Sess., 1969, p. 83.

use, and if solid waste must be disposed of rather than left lying around in junk yards.

One answer to these problems lies in the application of advanced technology to the minerals sector. The potential impact of technology on fuels utilization, for example, is graphically illustrated in figure 3. The materials problems facing our society place six stringent demands on technology. These are:

1. To foster new techniques of discovery.

2. To foster use of materials which so far evade our efforts.

3. To apply the principles of recycling more broadly.

4. To learn how to deal with low concentrations of useful materials.

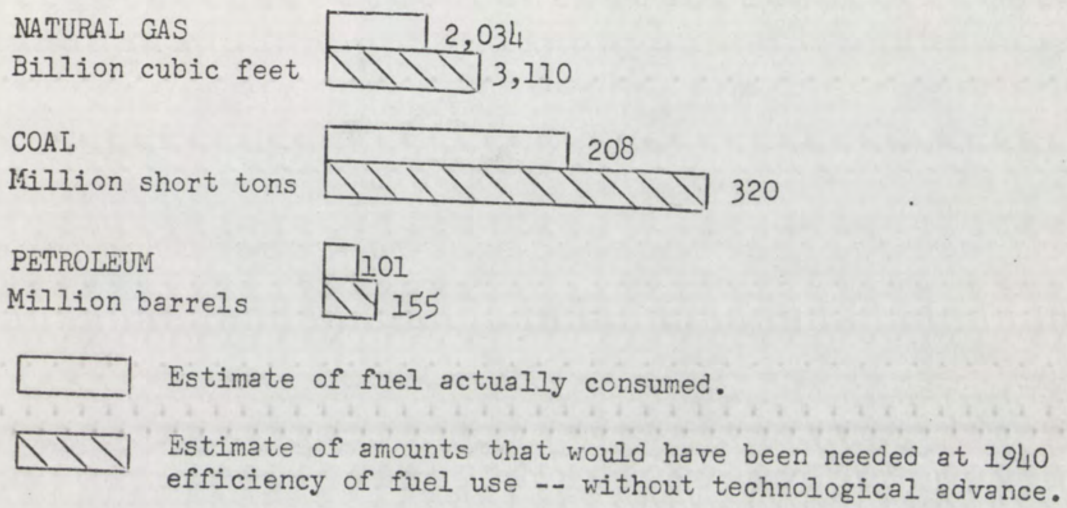
5. To lessen or eliminate need for a scarce material by substituting one that exists in greater abundance.

6. To develop and use more economically the resources that are renewable in nature.[12]

Failure to meet these demands will inevitably result in material limitations on our affluence. Landsberg states the policy implications clearly:

> At many points in this study the need for continued gains in technology stands out clearly; without such advances the ever-present tendencies for demand to outrun supply, save at increased cost and prices, cannot be held in check. . . . Continued advance in techniques of exploration for ores and of their extraction and processing, plus increased efficiency in getting heat and power from fuels, will be necessary to satisfy demands for mineral materials and energy. . . . The main escape hatch from scarcity is technological advance across a broad front, and behind this have to be large, varied, effective programs of research and development in science engineering, economics, and management. And to back up these efforts, in turn, there must be a strong system of general education at all levels.[13]

THE PERFORMANCE OF TECHNOLOGY, 1940-1960



THE PROMISE OF TECHNOLOGY, 1960-2000

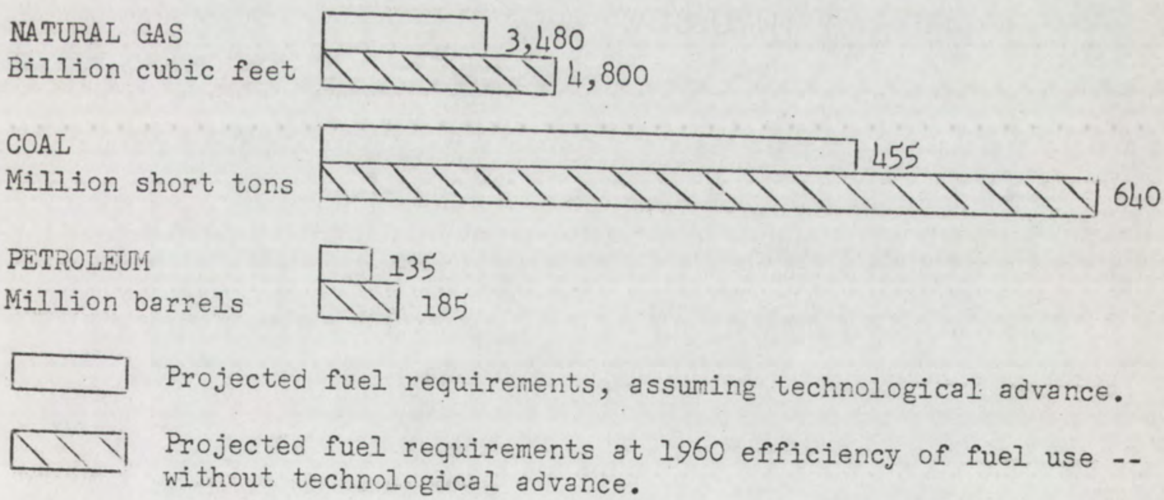


Figure 3. The Influence of Technological Advance on Fuel Requirements for Generating Electricity.

Source: Hans H. Landsberg, Natural Resources for U. S. Growth: A Look Ahead to the Year 2000 (Baltimore: The Johns Hopkins Press, 1964), p. 28.

Landsberg's call for a strong system of education brings out another critical problem facing the minerals sector -- the decline of the minerals education establishment. In this day of scientific accomplishment, the effective supply of natural resources is clearly more dependent on knowledge and facilities than on the existence of high grade deposits. But if technology is vitally needed, where will the expertise come from? This question assumes critical dimensions when we consider that in 1967 there were only seventeen educational institutions which had an accredited curriculum in mining engineering, and in 1969 only 110 mining engineers were graduated from American universities.[14] Figure 4 illustrates the educational crisis in the minerals sector. In 1963, the then Assistant Secretary of the Interior for Mineral Resources, John Kelly, placed an eloquent statement of this problem in the official record:

> The scarcity of creative people is one of the major forces affecting the minerals industry today. The manpower pattern developed in America of a working partnership between Government, universities, and industry has somehow passed by the minerals industry, particularly in the areas of exploration and development. There is not a really sustained effort within the minerals industry and the universities for basic research or for the development of creative and knowledgeable people. In a period when much has been done to take advantage of university resources and talents, the schools of mines in America have been allowed to languish. As a consequence, the minerals industry today is at a disadvantage when competing in the market for creativity.[15]

Six years later, the present Assistant Secretary for Mineral Resources, Hollis Dole, testified to the same problems grown more acute by six additional years of neglect.[16]

The absence of adequate public and private attention to the problems of technology in the minerals sector over the past hundred years has been remarkable. We are faced really with an almost pathological

GRADUATES IN MINERAL ENGINEERING

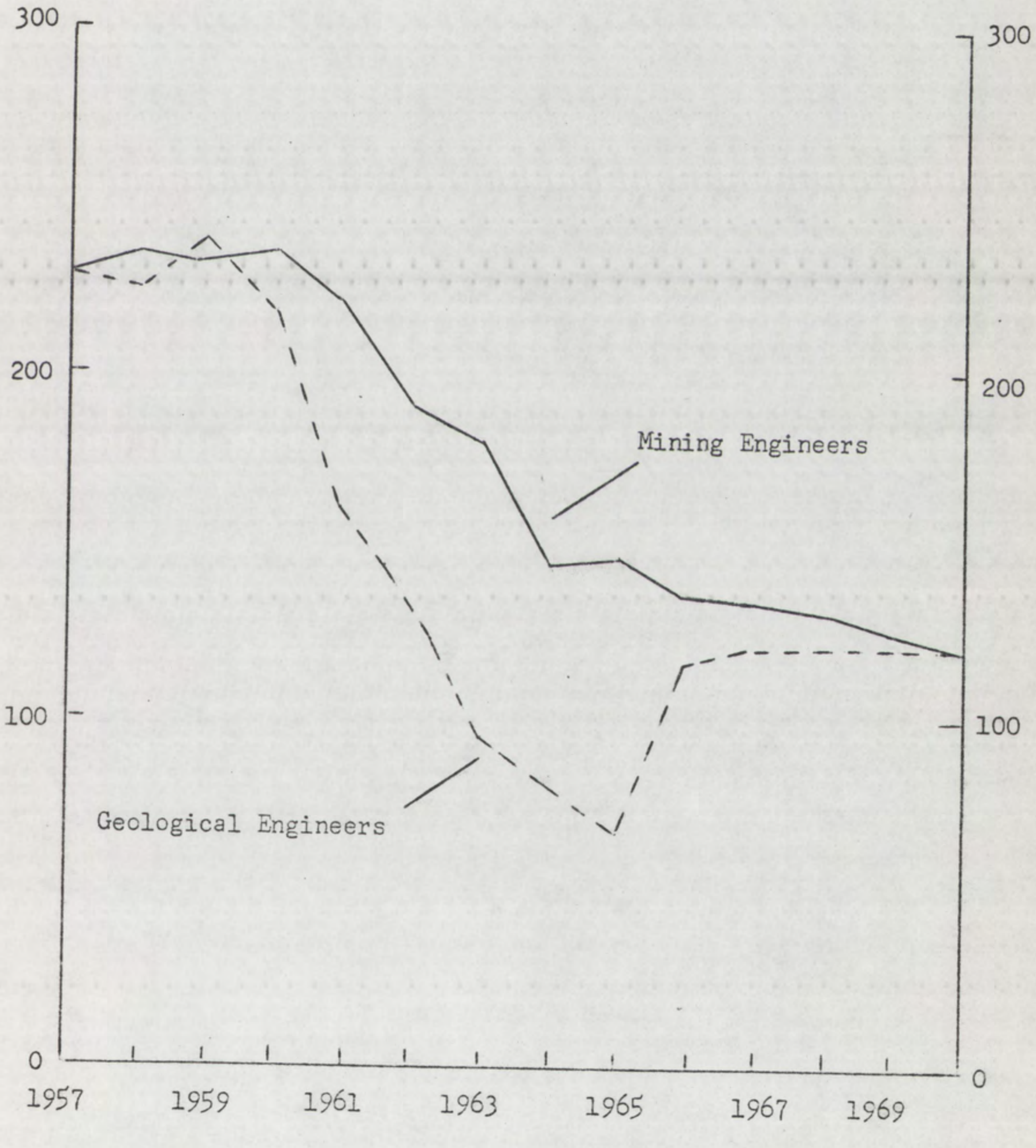


Figure 4. Graduates in Mineral Engineering.

Source: U.S., Congress, Senate, Committee on Interior and Insular Affairs. National Mining and Minerals Policy, p. 84.

lack of national concern. We have had no shortage of experts, politicians, academicians, and industrial leaders who have viewed the situation with alarm and who have sounded warnings. But nothing seems to happen on a national policy level, in the private sector, or in the academic world to start corrective actions. Federal mineral research activities are poorly funded, states provide virtually nothing, and the minerals industry, as we shall see below, is a niggardly supporter of research and development. Nor have the universities responded to the challenges by overhauling archaic curricula and upgrading their minerals programs. There seems to be a national tendency to take mineral resources for granted -- a kind of "gold rush" mentality which says that whatever we need will be found in a rich stake just over the next hill. No amount of warnings and alarms has served to mobilize sufficient action. What is needed now is not another description of the problems but more concrete, rational, aggressive proposals of institutions and programs to begin meeting the obvious needs of society.

B. THE TECHNOLOGICAL CONDITION OF THE MINERALS INDUSTRY

In our mixed economic system, the extraction, processing, and utilization of minerals are primarily the functions and responsibilities of the private sector operating in response to market conditions. Yet, the larger public interest requires a steady, dependable supply of minerals at reasonable social and economic cost in order to insure the health and strength of the national economy. Furthermore, the environmental effects, or external diseconomies, of minerals operations also require the guardianship of the public interest. Nevertheless, the public interest notwithstanding, the principal and most direct beneficiary of advanced technology is the competitive cost and profit position of private industry. Under these circumstances we might expect that private industry would bear the major burden of greatly expanded research and development effort; however, such is not likely to be the case.

Certain basic characteristics of the minerals industry lead us to expect that the private sector is unwilling or unable to support the degree of expanded technological effort required by the conditions of the general economy. The industrial structure in the minerals sector is not conducive to expanded technological effort. Very generally speaking, the minerals industries are characterized by a large number of relatively small producing units, intensive competition, high risk, heavy exploration and resource development costs, low and slow rates of return on capital investment, inadequate cash flow income, depleting resources, and vulnerability to loss of markets.[17] Clearly, the industry needs research and development; but the characteristics of the industry, and in particular its fragmentation, seriously inhibit substantial research and development investment.

The minerals industry, in fact, is not research intensive. The latest data compiled by the National Science Foundation show that the petroleum and primary metals industries, as shown in figure 5, rank well below the national average of funds spent for research and development as a percentage of net sales. Evaluation of research activity by the criterion of number of scientists and engineers per 1,000 employees also shows these industries to be well below the average of all industries.[18]

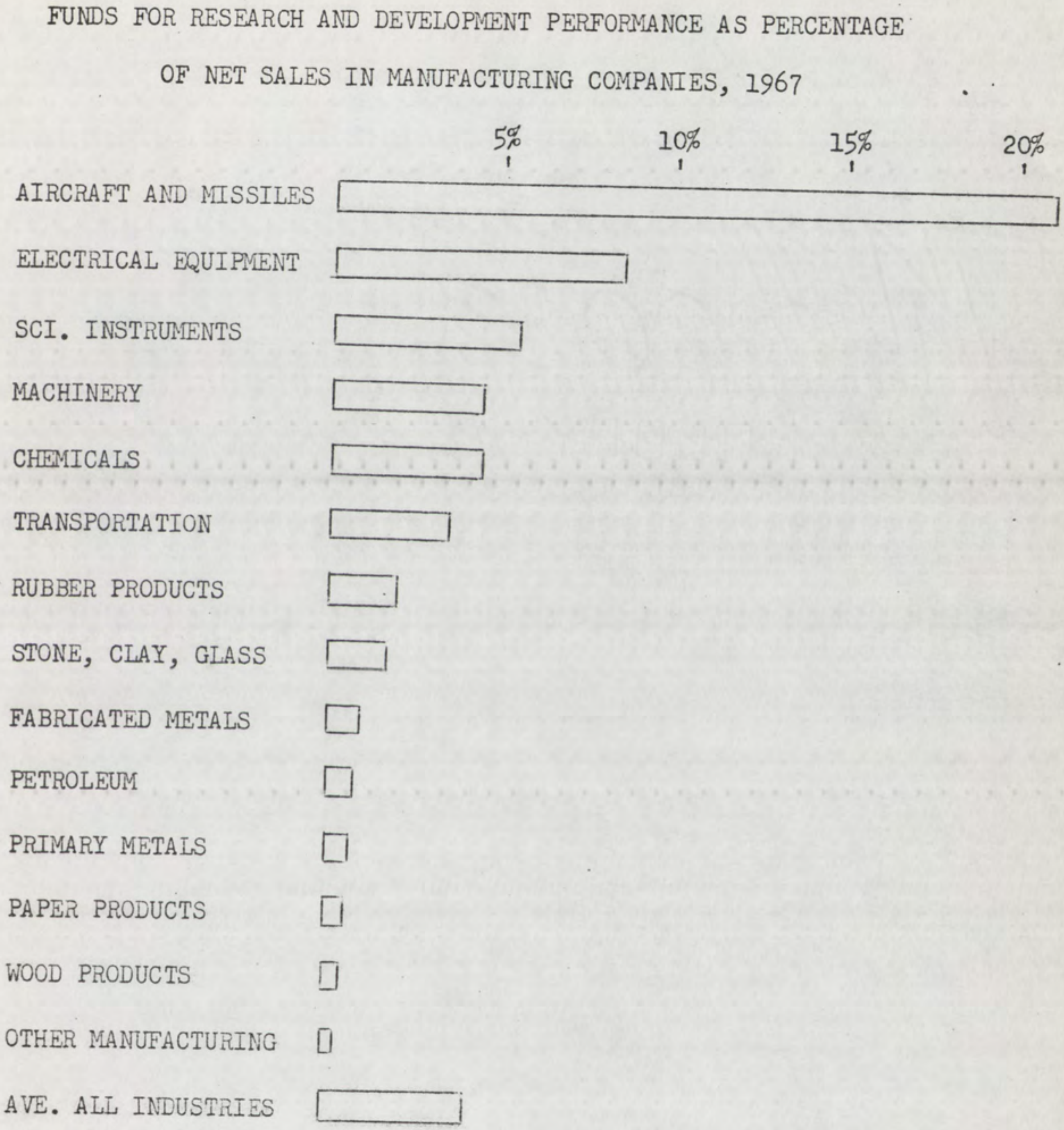


Figure 5. Funds for Research and Development Performance as Percentage of Net Sales in Manufacturing Companies, 1967.

Source: U. S., National Science Foundation, <u>Basic Research, Applied Research, and Development in Industry, 1967</u>.

While improved technology has been highly significant in enabling the minerals industry to meet extraordinary demand growth in the past century, the advances have largely been incremental improvements in equipment and materials-handling techniques and in the full utilization of older process improvements. The technology of the past will no longer suffice to meet the changing needs of our time. We now need a substantial new research base from which future improvements can be made. In the words of the Paley Commission eighteen years ago: "We shall have to increase the over-all effort of materials technology, and plan its whole pattern of research better than it has ever been planned before."[19]

The prospects of the required level of technological effort coming from the industry are remote. The structural nature of the industry is against it. The lack of research intensity and capacity within the industry is against it. Some fundamental conditions of economics in relationship to technology are against it. Economic analysis has tended to show that the market works very imperfectly in regard to the advancement of technology and that, as one close student of the relationship reports, "there are good reasons to believe that market incentives tend to cause business firms to spend much less than is socially desirable on research and experimental development."[20] If this is true of industry in general, it is particularly true of the minerals industry. We find some level of research expenditure in the petroleum industry; less in coal; and essentially none in primary metals, fabricated metals, and mining.[21]

To add to the problem, the present major concerns of leaders in the minerals industry seem to be matters other than technology. The common posture of the industry leans to concerns of special governmental favors and privileges, depletion tax policies, tariff protection, and subsidies, rather than advancement of technology.[22] A review of the statements of industrial leaders to the Senate Subcommittee on Minerals, Materials, and Fuels in 1969 reveals overriding concern with the above matters, and little comment on the need for improved technology.[23] These are, after all, mature industries which have been operating for a long time in accustomed ways. We perhaps should not expect great bursts of technological innovation.

Those industries which are research intensive are characterized by large size of producing units, a structural and behavioral framework of oligopoly, accumulation of uncommitted surpluses of capital, an ability to absorb uncertainty and high risk, opportunity for profitable investment in research, and heavy governmental support.[24] In 1967 companies in five industries reported eighty-four percent of all industrial research and development expenditures. The two leading industry groups in research and development expenditures (aircraft and missiles, 34%; and electrical equipment and communications, 23%) held their lead "primarily because of substantial Federal Government financing of their activities."[25]

The minerals industry meets none of the conditions of size, structure, or support which characterize research intensive industries. The Paley Commission summarized the situation very well:

> Thus, industry ordinarily undertakes materials research only when hard pressed -- that is, only after a crisis is already well developed. Individual companies have understandably only a limited interest in long-range research on problems whereby, if successful, they pay the bill for their competitors. On the other hand, the vigorous and resourceful attack necessary to anticipate impending

materials difficulties usually has not been forthcoming from Government either.[26]

The reference to the role of government opens up a new area of discussion. If the minerals industry finds the costs of long-range research to be more than it can accommodate, particularly when the chance of large success is remote, it may then either reduce its expenditures or ask for government support.[27] The latter course has generally been followed, and we have the justification for and continued existence of intra-mural governmental research efforts in mineral resources. The rationale for these programs is well expressed by an industrial research leader:

> Those few federal research projects which have to do with the application of fundamental scientific facts in order to maintain the welfare of the public at a distant time are usually connected with the depreciation of our natural resources. These are problems that cannot be justified by industry from the stockholders standpoint, not only because of the high cost, but also on account of the long time necessary for solution. The need for this research is always apparent, and it is this type of research that is asked for by industry.[28]

C. THE GOVERNMENT ROLE IN MINERALS TECHNOLOGY

Governments have traditionally been concerned to some degree with the supply and utilization of vital mineral products. One authority traces the governmental role back to the early limits of human history: "Government aid, regulation and participation in the mineral industry are not new; they date back to the time when man first adopted communal living."[29] In the American society, the governmental role is expressed in terms of stewardship, which implies management, conservation, and development of mineral resources. But this concept runs immediately into the problem of how a government can manage, conserve, and develop resources which are largely in the hands of private owners, produced and consumed in response to market conditions, and subject to the influence of private stockholders.

Even in a free enterprise economy, some relationship is necessary between government and the mineral industry, because minerals have a public utility as well as private property aspect. This is demonstrated in the requirements of national defense for critical materials. Also, the health of the total economy and environmental considerations offer compelling reasons for the relationship.[30] Under these circumstances, the governmental role is one of regulation of the diseconomies of minerals production and utilization, assistance and subsidy in the form of tax and tariff measures, analysis and information for policy decisions, and technological assistance. Technological assistance to the minerals industry has a substantial tradition in the United States. For example, the Bureau of Mines and the Geological Survey have provided excellent services for so long that they have been largely taken for granted by the industry.[31]

In general, governmental support of research and development for the private sector has three main justifications. Support is justified in programs where rapid rates of technological advance are required and where the public interest transcends private incentives, as in health and aviation. Support is justified in industries like agriculture where the conditions of the industry result in weak capabilities for research and development. And support is justified in basic activities such as basic research and education.[32] A case can be made for governmental support of minerals technology in all three areas.

Minerals research and development of ultimate benefit to the private sector is carried on primarily in the laboratories of the Geological Survey, National Bureau of Standards, and the Bureau of Mines. The Geological Survey efforts are directed at exploration and appraisal of resources. The National Bureau of Standards is concerned with the fundamental properties of materials. The Bureau of Mines conducts research programs specifically intended "to stimulate industrial production, processing, and use of essential minerals and fuels in ways that are socially and economically beneficial to the United States."[33] These research programs are in the areas of mining methods, metallurgy, coal, petroleum, explosives, and health and safety.

The activities of government agencies are directed, in the words of a former Director of the Bureau of Mines, "at promoting the wise development and use of the nation's mineral resources to sustain the economy and to assure adequate, dependable supplies at the lowest economic and social cost."[34] But the governmental efforts are poorly coordinated, fragmented, and of too small a scale to properly meet the requirements of the general economy. There is no national minerals policy, only a collection of unrelated laws and activities.[35] We have noted Senator Allott's attempt over a ten year period to have Congress declare a national minerals policy, without avail.[36]

The lack of national policy is joined by inadequate coordination within the government. The situation has not appreciably improved since the Paley Commission wrote:

> In spite of the number of Federal projects and of the considerable body of coordinating machinery, many problems in

> materials technology still fall into a no-man's land. These are in areas of insufficient immediate interest to industry that -- except in emergencies -- are either overlooked by Government agencies or handled with little attention to the many related questions usually involved. . . . There is clear need for greater coordination of material technology, not only to avoid gaps, overlaps and collisions among Federal policies and programs, but also to orient and foster the entire national effort, private as well as public.[42]

Obviously the conditions in the minerals industry, minerals education, and government require substantial alteration if the challenges and requirements of adequate mineral resources for the nation are to be met. On many occasions the government has been exhorted, often by its own officials, to pull everything together, to mobilize all the minerals interests into some kind of partnership of government, industry, and universities. We cannot help but wonder if a partnership of the three parties, in their present condition, would really achieve the required solutions.

Any realistic partnership must recognize and overcome the limitations of the partners. The first requirement of an effective partnership is for government to put its own house in order by deciding on objectives and policies of governmental action in the minerals sector. A second requirement is to bring about a strengthening of the research capacity in private industry. This can be done only through a commitment of resources, both from industry and government, to the achievement of technological objectives. It is perhaps no accident that those industries which are research intensive are also those which are heavily involved in programs underwritten by the government. A third requirement is for the remaining minerals education establishments to overhaul and vitalize their curricula and, again with governmental support, to expand their research and educational activities in the minerals area.

Assuming that achievement of the above requirements is desirable in the national interest, we may well ask what institutional mechanisms would be most effective. Finding a tentative answer to this question is the concern of the following chapters.

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CHAPTER III

IMPLICATIONS OF INSTITUTIONAL CHOICE AND THE NEED FOR CRITERIA

As the problems facing the minerals sector of our economy threaten to drive up the cost of essential materials, the application of knowledge and technology through research and development represents a fundamental approach to problem solution. This approach raises additional problems of planning, coordinating, and implementing large-scale technological programs in an industry which is characterized by individualism, fragmentation, pursuit of self-interest, and a relatively low level of research effort. If the need is evident, generally accepted and testified to by arrays of experts, what then is required in the way of policies, programs, and institutions to attack the problems? For guidance in this, we need to look closely at the methods and programs of agencies which have successfully mobilized the required resources to deal with substantial technological challenges. Specifically, in terms of this study, how can science and technology be marshalled most effectively to meet the challenges of our minerals economy?

The basic questions facing science and technology today are the same basic questions that face any economic endeavor: What shall be produced? How shall it be produced, by whom, and with what resources? And for whom shall it be produced and how shall it be distributed?[1] In regard to science, the first question has been explored by many students of public science policy. The classic statement, leading to a discussion of criteria for scientific choice, was issued by Alvin Weinberg:

> It seems inevitable that the demands of science will eventually be limited by what society can allocate to science. We shall have to choose among different, often incommensurable fields of science -- between high-energy physics and oceanography or between molecular biology and material science. We shall also have to choose among the different institutions -- universities, government laboratories, and industry -- that receive government support for science. The first choice I call scientific choice; the second, institutional choice.[2]

Weinberg has discussed in detail his proposals for criteria for scientific choice. He has been joined in the discussion by a distinguished roster of other well known scientists.[3] These authors, however, have virtually ignored the question of institutional choice. We are left with little guidance for answers to the second fundamental economic question regarding the institutional methods for the performance of scientific and technological inquiry. It is this second question which is the concern of this chapter.

How the work of science is done, and by whom, is certainly as important as what is done. One conditions the other in a reciprocal relationship. In political and social terms, who does the work and under what circumstances is highly significant. Many observers have noted the instrumental effect that government research and development programs have had on the intermingling and interweaving of the public and private sectors of our society. When we inquire into the institutional reasons for why and how this has happened, we do not find answers; we find only justifications. Yet, the past must guide us as we plan technological programs for solutions to critical social problems.

The purpose of this chapter and the following chapter is to look at the past practice of institutional arrangements for science and technology in the public sector. We intend to assess the implications of past practice and to derive criteria for future institutional choice. The identified criteria will then serve as reference points in the development of institutional recommendations for the conduct of minerals research and development programs.

A. IMPLICATIONS OF INSTITUTIONAL CHOICE

Since 1940, the managers of federal science programs have utilized a bewildering array of institutional arrangements for the conduct of public research and development programs. For thirty years, the objectives of technological effort were fairly clear, although they are now being called into question. But if the objectives were reasonably clear, the institutional pathways to achievement of the objectives were exceedingly complex, involved, and inconsistent. A recent analysis of U. S. science policy states: "...the Federal agencies have adopted the structures most appropriate to their respective missions. This specialization, moreover, meets the wishes of the Executive Office whose main concern is the achievement of the great priority goals."[4] As we have fashioned research and development institutions for public program accomplishment, we have fastened our sights on the ends of technological policy and have allowed the institutional means to be bent to the ends. This is contrary to the predilection of the American political system for means rather than ends. This is also fundamentally contrary to the value system of science which extols means and distrusts ends.[5] Furthermore, the choice of institutional methods used to accomplish technological objectives has had profound, unexpected consequences for the American society. As we have allocated eighty percent of our federal government expenditures for research and development to non-federal organizations, we have effectively changed the American political and economic system.

The most striking implication of the last thirty years of federal science management has been the blurring of the lines between public and private enterprise. Perhaps the most coherent and incisive description of this latter day commingling of public and private affairs is contained in John Kenneth Galbraith's The New Industrial State. Galbraith looks at government-business interaction and reports: "The industrial system, in fact, is inextricably associated with the state. In notable respects the mature corporation is an arm of the state. And the state, in important matters, is an instrument of the industrial system."[6] Galbraith views this as the central trend in American economic and political life, and he holds the dynamics of advanced technology as principally responsible. Apparently then, one unanticipated consequence of massive federal support of science and technology since 1940 has been the recasting of American society.[7]

The rapidly advancing complexity and increasing cost of technology, particularly atomic energy, space exploration, and modern weaponry, have thoroughly intertwined public and private interests. This is especially true in the space program where the interrelationships between NASA and its contractors have been recently described in Fortune magazine as a "new sociology."[8] As in the space program, so even earlier in the atomic energy program:

> "The atomic statute (Atomic Energy Act of 1954) appears to represent the culmination of the blurring process that has

> been taking place in recent years between private and public areas of our economy. The forces operating on competitive private industry ... have taken on many of the characteristics of those forces affecting a governmental undertaking."[9]

Nor is it just government agencies and industry that have gotten intermingled. Our universities are deeply involved, and a whole array of non-profit institutions of one kind or another are inextricably associated with planning as well as conducting government programs.

In effect, since 1940, the government has chosen on pragmatic and expedient grounds to develop a partnership with the private sector. This partnership has been officially sanctioned by the Bureau of the Budget in the well known Bell Report: "A partnership among public and private agencies is the best way in our society to enlist the Nation's resources and achieve the most rapid progress."[10] With this official statement in mind, the dominant practice of the federal government since 1940 has been to place increasing emphasis on non-federal institutions for the conduct of federal research and development programs.[11] During these years, the ideological issues and the principles of public versus private enterprise were not faced directly by government science policy makers.[12]

The results of institutional expediency, pragmatism, and the bending of means to ends has yet to be reckoned. Don Price has pointed out: "No one seemed to be very surprised when ... the postwar atomic energy and space programs were built on a system that was not an extended bureaucracy but a network of contracts with private institutions."[13] But if no one was surprised, then no one really faced the issues. Nor have we yet made explicit the institutional philosophy or political science concepts which tie government science and industry so intimately together.[14] Michael

Reagan continues to prod us in the direction of facing the issues when he writes:

> "The practical administrator usually only asks of a system or a process: Does it work? If it does, he is satisfied. We, on the outside, however, should also be asking: What does that particular process do to our system? Is it harmful or beneficial in its side effects, in the long as well as the short run?"[15]

Peter Drucker views the accelerating public-private partnership with alarm and concern for the fate of the individual.[16] Others are more sanguine. Clarence Danhof summarizes: "Given the nature of the R & D process, this intermingling is essential to the system. ... An agency's program is built upon contributions from many sources."[17] Alvin Weinberg is even more relaxed: "This trend toward blurring of our institutions by each taking over historic functions of a related institution is very common today. In industry, it is called diversification."[18] Weinberg is echoed by Don Price who points out that the relationship between government and its research and development contractors "is more like the administrative relationship between an industrial corporation and its subsidiary than the traditional relationship of buyer and seller in a free market."[19]

Despite such reassurances, we have every reason to become concerned over the intermingling of public and private institutions in the conduct of the public's business, for this strikes directly at the concept of responsibility and accountability of government. One cause for concern is that the private sector may become dominant in the partnership, to the detriment of the public interest.[20] The reverse aspect of this danger is "that government by procurement, unregulated, can be as dangerous to the free enterprise system as any other form of rule not responsive to the electorate."[21] If the partnership is equally dangerous to both partners, we may take some comfort in the hope that a balance of power will prevent undue advantage to either party.

We can take little comfort in resorting to the law. There are serious constitutional uncertainties in the process of the Federal government contracting-out its responsibilities to private parties, and legal theory "must be rather severely wrenched to assimilate such a major deviation from orthodoxy."[22] Nonetheless, the strengths of the partnership will keep it in business. We must be aware, however, and design our institutions carefully, for as Arthur Miller states: "Democratic government is <u>responsible</u> government -- which means <u>accountable</u> government -- and the essential problem in contracting-out is that responsibility and accountability are greatly diminished."[23]

In democratic political theory, there is another side to the responsibility-accountability coin. If institutions are commingled, we have the elements of representation and participation of a broad public sector in public programs and decisions. The concepts of representation and participation are very much in the mainstream of the theory and practice of democratic government. Another word for it would be pluralism. There is no question that the recent development and operation of American science policy has been pluralistic.[24] Sanford Lakoff has put it very well:

> "In short, if we consider only this one sector of the scientific establishment, the public sector, we see a structure made up largely of horizontally parallel rather than vertically integrated segments. The scientific establishment in the government is hardly monolithic or

regimented. It too is distinctly pluralistic."[25]

What we are really talking about here is the influence of institutional patterns of research and development on the gestation of a new Federalism. Don Price described and defined it as "Federalism by Contract" in 1962: "And now, in the research and development programs, the scientists have brought to its most complete development an improvised system of federalism that makes use of private institutions for the conduct of federal programs."[26] The New Federalism seems to be a non-partisan issue. In 1967, President Johnson charged a study commission to investigate the best techniques for public and private collaboration.[27] In 1970, President Nixon has called for a New Federalism which will return power to the people.[28]

The New Federalism can have unhappy connotations. If we mean by it a great giveaway of federal funds and an abandonment of federal policy and program responsibilities, the implications are disastrous.[29] On another front, if the New Federalism means a closed system which is operated by and for the convenience of its governmental and contractor-subsidiary components, then we must be greatly concerned over the representation of the larger public interest and for the interest of the individual citizen-consumer-taxpayer. Galbraith's version of the industrial state implies a closed system, a fusion of economic and political power. A sense of the threat of such a closed system perhaps provides the motivation for the general public's turning away from technology and the rationalism of science, and a popular turning to a new romanticism and a search for new values.

If the foregoing implications are to be avoided, the mixture of politics and technology now places new demands on policy makers. As James McCamy puts it: "The new politicians have to blend public decision and private execution. ... They have to maintain the new mixture of public and private enterprise without allowing the state to become totalitarian."[30] If this can be accomplished, then the New Federalism takes on the meaning of a new and broader public participation in government policies, decisions, and programs.

The direction which the New Federalism will take is a critical issue which planners and managers of national research and development programs must take into account. We must begin to face the political, social, and economic implications of institutional choice. These are considerations which must be emphasized in the design of institutional arrangements for the accomplishment of national technological objectives. We can do this by recognizing the issues and by devising institutional mechanisms which reflect our concern.

B. THE INSTITUTIONAL ARRAY

The menu of possible institutional arrangements for the accomplishment of research and development is lengthy, complex, and like that found in any fine restaurant, undoubtedly expensive. For example, in fiscal year 1968 the federal bill for research and development was 16.7 billion dollars, of which 13.1 billion was allocated to a variety of extra-mural operations, with the balance going to in-house activities.[31] We are concerned here with the basis of choice between intra- and extra-mural operations, contracts with private profit-making firms, grants for university research, quasi-government laboratories, RAND-like organizations, COMSAT-like enterprise, and an array of intervening possibilities and combinations. In a recent essay, Norton Long discusses policy choices regarding the allocation of resources between levels of government and between the public and private sectors. He holds that the choices "depend on the outcomes we value and the most effective mix of . . . initiatives for producing the desired outcome."[32] To date, effectiveness has been the principal concern, and significant political, social, and economic outcomes have not been given due consideration.

The institutional possibilities have all been used in varying combinations by different agencies with varying degrees of success. We find no consistency. The Atomic Energy Commission relies almost exclusively on extra-mural operations; NASA maintains some intra-mural capacity but relies principally on contracts and grants; NIH has strong in-house capacity but also places heavy reliance on the educational and non-profit sectors; the National Bureau of Standards operates predominantly in-house. Each of these agencies has been remarkably successful. Each has also had problems.

Analysis of the contribution of organizational style to success or failure of technological programs would be an important study. Dwight Waldo called for such a study nine years ago: "If our future depends upon the effectiveness of our research effort, then it would seem to follow that one of the first things we need to research is the effectiveness of different styles of research organization and operation."[33] Measuring the effectiveness of research organizations is a knotty problem, as attested to by James McCamy:

> "After twenty years of large-scale administration by contract, we still cannot measure results against what might have been accomplished by government doing all the work in its own agencies, with its own people. We face the old familiar lack of a yardstick to measure social results in the accomplishment of public administration, before and after. ... The more important results can be measured only by judgment. To measure the achievement of government when it does its own research compared to when it contracts for research is as different as to measure education. It can be done, but the results make no sense."[34]

Our interest here is not to contend with these difficult questions but rather to look farther back and to seek the implications of decisions to organize and operate in one way or another.

For purposes of further discussion and analysis, eight institutional alternatives are identified and defined in the following pages. Obviously, these eight alternatives do not exhaust the examples of past and present practice, nor do they blanket future possibilities. They are merely representative of the institutional mechanisms which are commonly utilized in the conduct of federal research programs.

1. National Laboratories. These include government-owned and controlled activities and installations, either operated by government personnel or by contractor personnel for the government. The federal government spent approximately 3.5 billion dollars on directly operated in-house laboratory facilities in fiscal year 1968.[35] Although the largest federal technological program areas -- defense, space, atomic energy, and health -- are heavily committed to extra-mural operations, the responsible agencies maintain significant in-house capability. The domestic research and development programs in natural resources, agriculture, and commerce are largely in-house oriented.

Under National Laboratories, we are also including government facilities which are contractor operated. The use of contracts to establish and operate government-owned and funded facilities, which prior to World War II would have been intra-mural, is characteristic of atomic energy research operations. The Defense Department and NASA also make limited use of this concept. There were 58 facilities in operation in 1964. These facilities are managed by private institutions or universities under contracts of marked continuity. They are closely identified with a single agency and have responsibilities directly tied to the mission or program of the sponsor. Examples of contractor-operated government facilities are the Los Alamos Research Laboratory and the Oak Ridge National Laboratory of the AEC, and the Jet Propulsion Laboratory of NASA.

2. Industrial Contractor Facilities. These include government research and development activities which are performed in the profit sector of the economy. The significance of this activity is represented by Department of Defense calculations that in fiscal year 1968 contracts with industrial firms for research and development represented 68 percent of the total defense technological performance.[36] Research and development contracting with the private sector involves products which range from theoretical development to actual production of hardware and services. One major feature of this activity is described by Michael Reagan:

> "R&D contracts cannot be let by competitive bidding, and major contractors often become permanent dependents of the government -- which thus becomes reciprocally dependent on a small number of major firms. Most of the normal market protections are therefore unavailable; a contracting officer rides herd on the performance as a surrogate for the missing

competitive element."[37]

3. <u>University and Non-Profit Organization Facilities</u>. Federal funding of university research is characterized by projects in academic departments following the interests of the scientific community.[38] The principal funding device is the grant either to the educational institution or more commonly to individual researchers and teams. Research and development in non-profit institutions covers a broad range of projects and scope of operation. At one end, projects may be academically oriented at one of fourteen major not-for-profit institutions such as the Batelle Memorial Institute, Mellon Institute, or the Stanford Research Institute, nearly half of which have a university affiliation.[39] In contrast, non-profit institutions such as Sandia Laboratories, which is operated as a non-profit subsidiary of the Bell System, perform major design, development, testing, and production monitoring of nuclear components and systems for the AEC.[40] Major agency supporters of university and non-profit research activities are NASA, Department of Defense, AEC, National Institutes of Health, and the National Science Foundation.

4. <u>University Consortiums</u>. In cases where the public programs are of wide scientific interest and broad scope, several universities may join together to provide facilities for federally supported research. One example is the National Center for Atmospheric Research, (NCAR), sponsored by the National Science Foundation, and operated by a private corporation consisting of 27 universities from all parts of the country. Another example is the Virginia Associated Research Center (VARC) which was established as result of an agreement between NASA and the Commonwealth of Virginia. The VARC is a cooperative venture of the College of

William and Mary, University of Virginia, Virginia Polytechnic Institute, and the Medical College of Virginia. The Center manages NASA's Space Radiation Effects Laboratory and operates programs in which graduate students and representatives of other institutions can participate.[41]

5. University-Government Cooperative Enterprise. This arrangement implies a joint venture between a university and a government agency to establish, maintain, and operate a research installation for projects of mutual interest. The clearest example of this arrangement is the Joint Institute for Laboratory Astrophysics (JILA), established by partnership between the University of Colorado and the National Bureau of Standards. In the JILA, federal and university personnel are virtually indistinguishable as they work together, share facilities, and participate in university functions. One result of this arrangement is that "the Government side of the operation is relatively unhampered by the usual problems relating to the adequacy of ceilings and logistical support services."[42]

6. Bridging Institutions between Universities and Government. Relationships between government and universities have been subjected to two contrasting criticisms. One points to the need for greater interaction. The other views with alarm the impact which massive federal support of university research is having on the structure, mission, and effectiveness of academic institutions. These criticisms have led to the establishment of bridging or buffer institutions to stand between government and academia. A leading example of this kind of institution is the Lunar Science Institute (LSI) which was established in 1968.

The LSI is funded by NASA but established by the National Academy of Sciences with the cooperation of a group of universities. The principal function of the LSI is to insure the interaction between university scientists, staff scientists of the Manned Spacecraft Center, and the Institute's own staff and visiting scientists. Thus, LSI has become a kind of "academic way station" between NASA and the academic community.[43]

7. RAND-Type Institutions. The years following World War II have seen the remarkable leap to prominence of a new kind of non-profit organization which specializes in systems research and development, program analysis, and, most controversially, policy advice to government agencies. The prototype of this form is the RAND Corporation. But RAND is not alone in a field now crowded with many others including the Institute for Defense Analysis, Center for Naval Analysis, Research Analysis Corporation, and the Systems Development Corporation. It has been suggested by some that this form of institution should be fostered and encouraged as an effective means of obtaining quality analysis and advice. Many agencies in the civilian sector are now utilizing such institutions, and RAND itself is looking far beyond its original emphasis on national defense, intelligence, and security. These institutions have also been viewed from other quarters as threats to government accountability and responsibility because their influence on policy is not subject to the view or control of the people.[44]

8. Public/Private Corporations. In 1962, Congress passed and the President signed the Communications Satellite Act establishing a corporation which is a blend of public and private enterprise for the purpose

of carrying out an important technological program. The result is COMSAT, a private firm which issues common stock under a congressionally prescribed method, and which has three of its fifteen directors appointed by the President of the United States.[45] One reviewer of this remarkable corporation states: "COMSAT is an experiment, a social experiment, ... to see whether new forms can be developed that will transcend the obsolete notion of society as a competition between the individual and the state."[46] COMSAT may well represent the ultimate in the intermingling of public and private interests in the accomplishment of technological effort in the national interest.

C. THE NEED FOR CRITERIA

A search of available literature indicates that no adequate standard criteria for institutional choice have been developed. Weinberg indicates that such criteria exist, but he does not elaborate.[47] Here and there we do find evidence of management considerations, administrative factors, reasons, and justifications for choice; but we are not easily able to determine the criteria which, for example, moved the AEC to contract-out the science and technology for atomic energy and yet, in effect, to create a network of national laboratories which are to all intents, purposes, and appearances as in-house as any Bureau of Mines research facility.[48]

In his excellent review of the literature of scientific choice, Bruce Smith initiates a discussion of institutional choice, but he does not follow through beyond stating: "For many important questions of scientific choice ultimately boil down to questions of institutional choice."[49] Smith then abandons the search, but he does lead us to Carl Kaysen's substantial discussion on the subject:

> Kaysen appears to go farthest in the direction of stressing the means of reaching decisions on science policy. If we can devise the appropriate administrative machinery, which will provide both deliberate and in some sense representative choices, then many of the substantive issues of science policy will be resolved as a matter of course. ... Kaysen sees the search for appropriate administrative mechanisms as a more promising approach to the allocation of scientific resources than the inventing of new allocation formula.[50]

Congress has begun to express some interest in institutional criteria. In 1968, the House Committee on Science and Astronautics asked Harold Finger of NASA: "What criteria are there to determine if NASA should perform work in-house, contract to industry or universities, or have the work performed by another government agency?" He replied:

> The question of what criteria are used by NASA to determine whether NASA should perform work in-house, by contract, by universities, or by another government agency really depends on a set of complex management factors which must be appraised on a case-by-case basis. There is no set of criteria which are followed in every instance. There are, however, several general policies which NASA follows as a basis for decision-making.

Finger went on to refer to policies of NASA and the Executive Branch and to the necessity of maintaining in-house competence. He then suggested nine "management considerations," but at no time did he refer to the fundamental issues of the relationship of institutional choice to political, economic, and social relationships.[51]

The same committee asked a similar question of Phillip S. Hughes of the Bureau of the Budget. His reply contained a clear statement of guidelines, if not criteria, by summarizing the contents of Bureau Circulars A-49 and A-76 and the Bell Report.[52] This statement is indicative of the best government thinking to date on this subject and is therefore quoted at some length:

> In our judgment there are two principal alternatives for accomplishing the Government's R&D work. Either existing or new in-house facilities must be used or arrangements must be made to perform the needed R&D by contract or grant with industrial, educational, State or local governmental and not-for-profit organizations. . . .
>
> Precise criteria for choosing among alternatives are at best difficult to develop, but there are a number of guidelines which an agency can consider in making its choices. For example, BOB Circular A-49 requires each agency to establish criteria for the use of management and operating contracts and suggests guidelines for such criteria. The Bell Report of 1962 discussed the natural advantages of direct Federal operations and the various patterns of contracting now in use and included the following general guideline for choosing among alternatives which we believe is still valid:
>
> ". . . Not all arrangements, however, are equally suitable for all purposes and under all circumstances, and discriminating choices must be made among them by the Government agencies having research and development responsibilities. These choices should be based primarily on two considerations:
>
> "(1) Getting the job done effectively and efficiently, with due regard to the long-term strength of the Nation's scientific and technical resources; and
>
> "(2) Avoiding assignments of work which would create inherent conflicts of interest."
>
> . . . .
>
> With respect to the factor of cost, BOB Circular A-76 provides guidance for agencies to decide among alternatives on the basis of cost comparisons. However, . . . program requirements and management considerations are the most compelling determinants for choosing alternatives in the research and development area.

The need for criteria has been expressed both by administrators and scientists. James E. Webb states the need eloquently:

> There is no doubt that we have the technical tools to free our society of many of its burdens and to carry it to new levels of achievement. What we need is an operating concept that requires us to find ways to use these tools deliberately and purposively to reform our society and to ensure continuing progress toward the great goals we set for ourselves long ago.[53]

Webb also remains alert to the implications of organizational choice when he raises the question of our ability to "organize ourselves to achieve effectiveness and efficiency in ever larger and more complex and taxing jobs and still retain our democratic ways."[54]

On a more practical plane, Elmer Staats points out the significance of institutional choice criteria: "One of our chronic and very difficult, problems has been to maintain some balance between in-house and extramural research. ... But we still don't have a clear picture of when it is best to undertake in-house and when it is best to undertake it by grants or contracts."[55] And William D. Carey believes that "the great remaining question is how government, the scientific community and industry will find common ground in stipulating the substance and priorities of these [science and technology] goals and strategies."[56]

The view of the scientist is even more practical. As Dr. James R. Killian, Jr., told a Conference on Research and Development and Its Impact on the Economy: "We need to find ... new institutional patterns and relationships to provide research facilities adequate to deal with modern research techniques."[57] Already we can see that institutional criteria must include considerations of values, objectives, administration and management, and the process and techniques of research and development. It is also clear that technological policy-making has suffered from the lack of criteria.[58]

The federal government is notably ambivalent toward the confused state of institutional criteria. The government bewails the absence of criteria; it is responsible for the confusion; and it excuses the confusion as a matter virtually of official policy. For example, William

Carey states the official complaint clearly:

> Meantime, the executive branch ought to decide what it wants to do about grants versus contracts, university cost participation in research, indirect expense allowances, inconsistencies in administrative controls, in-house versus contract research, the future of national laboratories, and over concentration of university research.[59]

On the other hand, the government causes the confusion through its predominant role as funder but not operator of technological programs.[60] And the government excuses its own confusion, as in the Bell Report:

> We consider it necessary and desirable to use a variety of arrangements to obtain the scientific and technical services needed to accomplish public purposes. ... Each agency should be encouraged to seek new and better arrangements to accomplish its purpose.[61]

More recently, Robert H. Kreidler speaks for the President's science advisers when he says:

> No single, easy, administrative policy can take account of the diverse objectives of all federal agencies and the varied interests of all private institutions in financing research facilities. The President's science advisers must try to be resourceful and wise in conceiving new policies for equipping science with the tools of scientific advice.[62]

Unfortunately, an exhortation to be resourceful and wise is not an adequate basis for institutional decisions. Kreidler's statement perhaps reflects a condition surrounding institutional choice which Michael Reagan has described for scientific choice as a "wistful longing for the 'good old days' of 1950-64 when competing claims were handled by increasing funds sufficiently to satisfy all claimants simultaneously."[63] In institutional terms, the "good old days" meant that any kind of institutional choice could be made for any kind of reason. And everything seemed to work. Now, in these relatively lean years for science, the choices are more difficult, and they need to be more rational, objective, open, and systematic.

Again speaking of scientific choice, Hendrik W. Bode points out: "We are living in a pluralistic world, and the problem of scientific choice becomes in the long run a problem of nonscientific judgment among these different conditions."[64] Certainly then, institutional choice must also be a problem of judgment among relevant variables. In the following pages, we describe criteria which may serve to introduce a greater degree of systematic, objective, and open decision-making into the process of institutional choice.

FOOTNOTES for CHAPTER III

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2. Alvin M. Weinberg, Reflections on Big Science (Cambridge, Mass.: The M.I.T. Press, 1967), p. 65.

3. A fine collection of articles on scientific choice is contained in Edward Shils, ed., Criteria for Scientific Development: Public Policy and National Goals; A Selection of Articles from Minerva (Cambridge, Mass.: The M.I.T. Press, 1968).

4. Organisation for Economic Cooperation and Development, Reviews of National Science Policy: United States (Paris: OECD, 1968) p. 97.

5. Don K. Price, The Scientific Estate (London: Oxford University Press, 1968), p. 66.

6. John Kenneth Galbraith, The New Industrial State (Boston: Houghton Mifflin, 1967), p. 296.

7. Cf. Sanford A. Lakoff, "Scientific Society: Notes toward a Paradigm," in Science and Policy Issues: Lectures in Government and Science, ed. by Paul J. Piccard (Itasca, Ill.: F. E. Peacock Publishers, Inc., 1969, p. 61: "... the fact remains that government involvement in R and D has fostered a significant change in the social structure. We must now begin to think of government as a continuum involving both public and private agencies. The old separation of government and society is obsolete. Political relations must now be understood as a process of bargaining and negotiation among public and private agencies in which politicians and private leaders function as brokers and overseers in the effort to apply science and technology to social concerns."

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15. Michael D. Reagan, The Administration of Public Policy (Glenview, Ill.: Scott, Foresman and Company, 1969), p. 224.

16. Peter F. Drucker, The Age of Discontinuity: Guidelines to our Changing Society (New York: Harper & Row, 1968), pp. 243ff.

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23. Ibid., p. 227.

24. William D. Carey, "Science Policy Making," in Decision Making in National Science Policy: A Ciba Foundation and Science of Science Foundation Symposium, Anthony de Reuck et al, eds. (Boston: Little, Brown and Company, 1968), p. 139.

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36. U. S., Congress, House, Committee on Science and Astronautics, Utilization of Federal Laboratories. Hearings before the Subcommittee on Science, Research, and Development, 90th Cong., 2nd Sess., 1968, p. 147.

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CHAPTER IV

CRITERIA FOR INSTITUTIONAL CHOICE

At this point in our nation's history, we are in the midst of a reappraisal and revision of our national technological priorities. As the mood of the nation swings away from the old triumvirate of national defense, space, and atomic energy, and toward a new triumvirate of natural resources, environment, and urban affairs, the priorities for basic and applied technology are also shifting. New technological policies, programs, and institutions are needed to attack new problems. A new range of issues is arising: "How can science and technology serve civilian society? How can you bring scientists, engineers, politicians, entrepreneurs, ideas, and capital together to serve the nation's new social and technical needs?"[1]

In an attempt to answer this question, we have identified twenty-five criteria which influence institutional choice within government research and development programs. These criteria have been grouped for discussion purposes into eight categories. Some duplication and overlapping will exist, but the total list of criteria provides a useful framework for analysis.

A. NATURE OF THE RESEARCH AND DEVELOPMENT PROGRAM

This category and the one following provide direct crosswalks from considerations of scientific choice to institutional choice. Here we are concerned with the type of research and development effort. For convenience we have modified the categories as specified in the Defense Department:[2]

1. Basic Research: Investigation of basic physical or behavioral phenomena, usually not involving extensive experimental hardware.

2. Exploratory Development: Applied research and the design of experimental hardware to test new principles and ideas.

3. Advanced Development: Development of hardware for experimental and developmental tests; design and test of components and systems prior to a production decision; and production planning and designs for systems approved for production.

Institutional choices based on the nature of the research program are commonly understood and applied in government. Thus, Wade Sewell states:

> By and large /basic/ research is carried out on a grant basis, exploratory development in government laboratories and the more advanced stages in development by contract although there are, naturally, exceptions to this generalization. Such an arrangement is rationalized on the grounds (1) that research talent is found in universities and (2) that, because of the constraints they face in adjusting to changing levels of effort, Government laboratories should be most heavily involved in work with substantial funding stability.[3]

The experience of the last thirty years bears out Sewell's analysis fairly well, although the expected exceptions have occurred. The primary role of universities in basic research through the grant mechanism was noted by the Bell Report.[4] However, it should also be noted that the federally financed, university-operated research centers tend to be more involved in applied research of substantial scope and resource requirements on a contract basis.[5]

NASA has clearly marked out an institutional division of labor. The universities have provided NASA with basic research.[6] Research is then institutionally divorced from development which is the responsibility of industry under contractual arrangements. NASA retains the technical management functions, test facilities, and some in-house research capacity as a device to insure competent management of contractor and grant programs.[7]

The National Institutes of Health also have maintained an institutional division of labor. Basic research programs are accomplished through extra-mural grant programs with universities and non-profit organizations which have been NIH's main resource for extra-mural scientific programs. Research and project grants are characterized by undirected research, individual or small group effort, relatively small sums of money per project, a minimum of agency monitoring, and a basis of scientific merit.[8] Directed or applied research programs are operated by contractual arrangements, often with private laboratories. The distribution of NIH intra-mural effort, however, reflects the distribution of the total program. NIH does not provide a specialized institutional role for its intra-mural laboratories in basic or applied research.[9]

The AEC experience has also led to institutional specialization. The national laboratories are responsible for the development of concepts and the preparation of test and engineering models. The industrial contractors engineer components and provide pre-production models. Manufacture is done in industrial firms.[10]

The National Bureau of Standards provides a unique exception. Here, in keeping with Commerce Department tradition, the preponderance of research and development work is intra-mural. Hence, the NBS laboratories have a variety of functions ranging from basic research through applied research, development, and testing.

B. MERIT OF THE RESEARCH AND DEVELOPMENT PROGRAM

Alvin Weinberg's three external criteria of scientific choice are adopted here for analysis of their institutional implications:

4. Scientific Merit: The contribution of the scientific field to other neighboring scientific disciplines.

5. Technological Merit: The readiness of the technological field for exploitation.

6. Social Merit: The relevance of the technology to the solution of social problems and the realization of social goals.

These criteria are often implicitly linked with the nature of the research and development program. Thus, scientific merit is linked with basic research; technological and social merit with applied and developmental programs. If the implicit relationships are taken literally, then we might forecast a shifting of research support away from the universities and non-profit sector, which are the usual institutional vehicles for basic research, as social merit receives new emphasis in federal technology programs. However, the analysis of institutional choice criteria should not accept uncritically the implicit assumptions.

There is no question that the current priorities for research and development are shifting toward social needs and away from science for science's sake. For example, James A. Shannon of NIH has stated: "Our national program in support of science is entering a phase in which the decision whether to support a given field depends less upon technical considerations than upon social needs."[11] In suggesting a priorities framework for federal technology, Michael Reagan gives his highest priority to "social objectives defined as most urgent politically."[12]

The countervailing view is well put by the Office of Science and Technology:

> The persistent trend in government is to look from military and technological needs down through applied problems to directed basic research. Support of this "response research" is then arranged to solve the applied problems. Frequently this process results in doing safe, routine work and leads only to incremental progress and a pedestrian use of science . . . It has been pointed out frequently that successful utilization of science for technological purposes is based on an imaginative collaboration between potential users of science and scientists, not on guidance of basic research by practical goals.[13]

Regardless of how the argument between social and scientific merit turns out, the organizational implications are clear. For example, Weinberg has clearly stated his position: "Since universities are discipline- rather than problem-oriented, they are not the best institutions to help agencies solve their practical research problems. That function is better performed by government and industrial laboratories specially organized to perform it."[14] Weinberg again clearly draws the differentiation between the purpose of the government laboratory to exploit science and technology for the solution of social problems and the purpose of the university to educate.[15] He calls for an institutional solution to social problems by raising a question and providing an answer:

> Can one recast social problems to accentuate their technological character, and thus reduce them to a form that can be attacked by the existing, hardware-oriented government laboratories? . . . The proper instrument for the attack on such complex issues as the cities or transportation or water is a coherent institution . . . that can develop coherent doctrines with regard to such issues.[16]

Weinberg may be accused of following a line of argument that would be of maximum benefit to his Oak Ridge National Laboratory, but his basic division of labor between universities and non-academic laboratories is supported by Harvey Brooks, whose allegiances certainly lie with the academic world. Brooks states flatly that programs of scientific merit are best handled by universities, and programs of social merit are best handled by non-academic and national research centers.[17]

C. A CALCULUS OF PUBLIC AND PRIVATE INTEREST

The objectives and principal beneficiaries of federal research and development programs have institutional implications. The criteria under this category are:

7. <u>The Private Enterprise Value System</u>.
8. <u>Technology for the Public Sector</u>.
9. <u>Technology for the Private Sector</u>.
10. <u>High Risk and High Cost Technology</u>.

Basic to these criteria are considerations of American political and economic values. "That government is best which governs least" and "let the market process decide" are two homilies which affect the size, scope, activities, direction, and institutions of American government. The argument of classical economics is that the market mechanism provides the best means of determining the answers to the fundamental economic questions of what is produced, how it is produced, and how goods are distributed. However, classical theory will admit that it is not possible to provide for pure public goods and services (e.g., national defense, health, education, and welfare) through the market process. Therefore, government expenditures, including research and development, are justifiable in connection with the provision of public goods.[18] The national interest also requires technology which has primary benefit for a particular private sector or for the economy as a whole.[19] Public provision of technology for the private sector is a great deal more controversial than for the public sector.

The organizational implications of the American political and economic value systems are manifold. The doctrine of free enterprise finds official expression in the Bureau of the Budget Circular A-76, the essential purpose of which is "to further the Government's general policy of relying on the private enterprise system to supply its needs."[20] These value systems may well be the principal reason for the heavy national emphasis on extra-mural research and development effort.

Even where the technology is required for the public sector, there is a strong argument for the use of private enterprise and market mechanisms. Harvey Brooks is provocative on this point:

> In the area of "public goods" there is a growing feeling that the more public policy can achieve its goals by indirection rather than by direct subsidy of R and D, the more likely is an optimal solution to be achieved. Thus to the degree to which the public itself can be brought into the decision between technical alternatives through quasi-market mechanisms, the ultimate accomodation between public and private interests is likely to be more acceptable and workable.[21]

Other voices have included the Bell Report which was emphatic in its support of contracting-out as being in the American tradition. The National Research Council has gone on record recommending governmental support of industrial initiative.[22] The official doctrine has been that research and development contracting strengthens free enterprise. The net result in the last thirty years has been an increasing reliance on private contractors which has paralleled the rapid growth of federal research and development expenditures.[23] Ironically, this use of free enterprise in the conduct of public science programs has perverted the concept to the point that we stand now at least at the edge of a planned, statist economy.

One unanticipated consequence of the reliance on private enterprise in the conduct of research and development has been the rapid development and growth of a "hidden bureaucracy" -- private employees who really work for the government.[24] In 1960, the Bureau of the Budget raised a most interesting question: "In what sense is a business corporation doing nearly 100 per cent of its business with the Government engaged in 'free enterprise'?"[25] Shortly after World War II, Dr. Edward U. Condon, then Director of the National Bureau of Standards, issued a strong challenge against the contracting practice, calling it an evasion of civil service legislation. Condon called for an expansion of the intra-mural effort in research and development, but he found little support.[26]

A further consequence of this "evasion" is that the government is placed in a position of competing with itself for scarce scientific manpower. Not only does the government increase its own difficulty in recruiting talent for its intra-mural laboratories, it also induces competition between other sectors of the economy. For example, Harold Orlans reports: "Presumably the net effect of the government's bidding with its right hand (in research, development and procurement contracts with industry) against its left (in research and development contracts and grants at universities) for scientific personnel is to raise their wages, perquisites, and marketability."[27] Unfortunately, this competition has done nothing to increase the supply of scientific manpower.

The government-generated competition for scientific manpower has the net effect of reinforcing the tendency to obtain technological performance extra-murally. The financial support of university research has enabled the academic world to compete more effectively with the private sector. In the last analysis, an important rationale for institutional choice is that the work will go where the talent is, and the government has enabled and encouraged the private sector and the educational institutions to maintain their staffs. The process thus tends to feed on itself to the detriment of federal in-house capacity.

The fact that a particular technology may be required for the public sector (strictly needed by a government agency in the performance of its specific public function) seems to have had no consistent institutional implications.[28] For example, advanced technology for the most critical and sensitive defense requirements is contracted-out as a matter of course by the Defense Department or the AEC. On the other hand, the National Bureau of Standards or the Food and Drug Administration rely largely on intra-mural research and development in areas of standardization and regulation.

When federally supported technology is required for the purpose of stimulating a particular industry in the private sector or the economy in general, a new range of issues arises. Leading examples of governmental support of private sector research and development include the AEC's civilian applications programs, COMSAT, health, the supersonic transport program, agriculture, and natural resources research programs. The fundamental economic justification for such programs runs as follows:

> For certain kinds of activities essential to technical progress, external economies and uncertainties tend to drive a wedge between private incentive and social return, and for others scale requirements may dwarf the capabilities of unaided private initiative. To compensate, policies have evolved to increase private incentives, or to increase private capabilities. In a few cases the government itself has taken responsibility for a large share of the R&D effort to stimulate technological advance for general or private sector use.[29]

We might be led to suspect that governmental support for private sector technology would take the form of predominantly extra-mural activities; however, such has not been the usual rule. Research programs of the Departments of Interior, Agriculture, and Commerce have been predominantly intra-mural. The justification for governmental support in these program areas has generally been that the particular private sector in question has not been able to support the socially desired level of technology; therefore, the government has provided the support, not by developing private capability but by performing the technology in-house.[30] Other substantial program areas include health, aircraft, communications, and civilian applications of atomic power have been characterized by extra-mural operations. A subsidiary criterion to private sector technology appears to be the nature of the industry which is to be supported and the general level of its technology.

The issues involved in governmental provision of technology for the private sector are generally more controversial than those which are concerned with technology for the public sector. These controversies may tend to condition institutional choice. The principal argument revolves around considerations of spending government funds for technology which primarily benefits private interests. This controversy intruded seriously into the discussions and congressional action on the supersonic transport (SST) and the communications satellite (COMSAT). In regard to the latter, many officials felt strongly "that the government should not finance efforts that would yield private profits beyond the point at which the venture could stand on its own."[31] On another front and in another problem, the Director of the National Bureau of Standards felt constrained to point out very carefully that NBS did not "encourage or authorize the development of commercial or proprietary products."[32]

Most instructive in this regard is the dialogue which occurred in 1967 between the Director of the Bureau of Mines and Senator Anderson and others regarding a Bureau proposal to perform extensive research on rapid excavation methods (Project Badger):

> Senator ANDERSON. Who pays for this work? From where is the appropriation?
>
> Dr. HIBBARD. I believe that the research and development to stimulate this type program is properly the responsibility of the Government.
>
> . . . .
>
> Senator ANDERSON. I think one of the things that concerns me is the fact that industry would be primarily the

beneficiary in the sense industry would be engaged in the manufacture of this equipment. What sort of contribution does industry make? Obviously, we all will benefit by reduced costs and improved technology, but how is this handled from that standpoint?

Dr. HIBBARD. Industry contributed to the budget about $500,000 a year, which is largely associated with construction contracts. This is not a research-oriented industry. They are responsive only to competition and need.

. . . .

Senator ANDERSON. Is all the basic research being done by the Federal Government?

Dr. HIBBARD. It is largely being done by the Federal Government.

. . . .

Senator ANDERSON. Why should industry not be more involved in this? . . .

Dr. HIBBARD. . . . Equipment manufacturers are not the kind to undertake research necessary to produce the kind of advancement we are talking about here. . . .

. . . .

Senator ANDERSON. I mean the benefits flow ultimately like any improvement in science and technology to the people as a rule, but it seems to me industry . . . has a tremendous opportunity. If they are looking for growth . . . I would think the equipment industry would move into this area and say to their board of directors, "This is a neglected area and I think we ought to get on the stick and get with it." Is that not what business is looking for?

Senator MOSS. Is this not the key to the SST development? They decided industry would not do it, so the Federal Government moved in.

Dr. HIBBARD. It is going to be extremely expensive. Something industry is not going to do alone. . . .

. . . .

The CHAIRMAN [Senator Jackson]. I think this is important. I am very surprised industry has not come forward with a joint venture approach in which industry could make available its talent and facilities working in cooperation with the Federal Government.[33]

Project Badger's ultimate fate was not a happy one, and the Bureau of Mines did not receive an appropriation to undertake the research. One cannot help but wonder if the fate of the project might not have been different if the institutional arrangement for the project had been different. We may speculate for example that if the project had been designed to stimulate or support a program of research and development to be conducted on an extra-mural rather than intra-mural basis, the outcome might have been different. Certainly, those agencies which have emphasized extra-mural performance of research and development in the last thirty years have been greatly more successful in expanding their programs than has the Bureau of Mines.

Another consideration of research support for the private sector involves programs in which the economic cost and risk of the required technology are too large to be absorbed entirely by private industry but in which there is a substantial public interest. Sorting out the public interest in such programs as development of the SST, the communications satellite, and the civilian applications of the AEC is no easy matter. It is perhaps easier to draw clear institutional implications, because those programs involving high risk and high cost have usually been performed in some variation of extra-mural manner.

In the case of the SST, the costs clearly were beyond the capacity of industry. The decision to provide government financing was based on a combination of national pride, commercial interest, and potential military application.[34] As to choice of institution, there was never any doubt that the technology for the SST would be developed by the aerospace industry. In this case the private sector had the capacity and would do the job.

Development of the communications satellite raised serious questions regarding institutional form. The final result of two years of legislative pulling and hauling over the issues was the Communications Satellite Act of 1962. The Act was the culmination of attempts by the executive and Congress "to design a legally, politically, and economically viable entity to preside over the national effort to develop a system of space communications in association with other countries."[35] Again, the problem involved costs which were beyond the capacity of the communications industry. The institutional result is private in form but heavily interlaced with governmental participation and funding.

Finally, in the case of atomic energy, there was of course no existing private sector when governmental research began. Rather than build an in-house establishment, the government instead deliberately began developing a private sector. The theme of John Palfrey's early essay on this subject is "the resulting complexity of a relationship in which the government simultaneously regulates, subsidizes, promotes and competes with a 'private' industry that it brought into being by legislative fiat."[36] Palfrey's analysis in confirmed by Harold Orlans who tells us that the original decision to buy atomic technology by contract included a specific consideration of the eventual need to establish a civilian industry.[37]

D. EFFICIENCY AND EFFECTIVENESS

The efficiency and effectiveness of alternative institutional forms are major considerations in the process of institutional choice. Specific aspects of this category include the following criteria:

11. Competition between Institutions.
12. Availability of Facilities and Manpower.
13. Flexibility of Administrative Systems.
14. Relative Cost.

The Bell Report of the Bureau of the Budget provides us with the nearest approach that we have to criteria for institutional choice. In this document, the criteria relative to efficiency and effectiveness are given prominence. The Bell Report provides the following guidance:

> In selecting recipients, whether public or private for research and development assignments, the basic rule . . . should be to assign the job where it can be done most effectively and efficiently, with due regard to the strengthening of institutional resources as well as to the immediate execution of projects. This criterion does not, in our judgment, lead to a conclusion that certain kinds of work should be assigned only to certain kinds of institutions.[38]

The Bell Report then makes a kind of qualitative analysis of the advantages of the different kinds of institutions for different kinds of work. Thus, direct federal operations are particularly suited to research and development which directly supports the management functions of the agency; colleges and universities are traditionally oriented to basic research; university-associated research centers are suited for basic and applied research which requires large and expensive facilities; non-profit organizations provide a degree of objectivity and independence; contractor-operated government facilities have the advantages of government control without the disadvantages of administrative inflexibilities associated with federal employment; and private firms have advantages for advanced development programs requiring the quick marshalling of large and complex resources.[39] These capsule analyses, however, are not accompanied by any guidelines for making specific determinations of relative efficiency and effectiveness.

The Bell Report may be excused for its lack of precision, because considerations of relative efficiency and effectiveness of public and private research and development institutions are difficult if not impossible to handle. The prospects of arriving at equitable mechanisms for the evaluation of productivity are remote indeed. Realization of this has prompted economically oriented analysts to advocate a quasi-market approach featuring mechanisms of competition which would, as in a pure market situation, sort out the productive and non-productive institutions.

The essential statement of the concept of institutional competition is from Charles J. Hitch who addresses the question of research and development efficiency through manipulation of the institutional alternatives.[40] He advocates competition between industry and between agencies, and he also raises the question of how to curb the undesirable features of inter-agency competition.[41] Harold Barnett takes the same line of reasoning in advocating competition and multiple paths of development. Barnett cites the experience of the Manhattan District which sponsored "vigorous competition among different groups working separately toward the same objective, with great success."[42]

Two other authorities should be noted on the subject of institutional competition. Dr. William B. McLean, Technical Director of the Navy Undersea Warfare Center, relates competition to social values when he testifies:

> I believe the only nonsubjective measure of effectiveness in R & D must result from comparisons on a competitive basis. . . . Competition between . . . laboratories, or groups of laboratories, should be encouraged and the record of their accomplishments evaluated. Our abilities to satisfy society's needs are judged by competition and rewarded by success or failure. This process provides high incentives and high motivation.[43]

On a more philosophical level, Michael Polanyi uses the example of the economic market system as a prop for his argument for the freedom of science from the threatened possibility of social control. Polanyi states: "We may affirm that the pursuit of science by independent self-coordinated initiatives assures the most efficient possible organisation of science."[44]

The institutional implications of competition are multifaceted. Competition implies utilization of a variety of institutional mechanisms to achieve policy objectives. It also implies the absence or control of prejudgments and favoritism in the selection of institutions to perform research and development. An important illustration of the hazards of inadequate competition is contained in recent critiques of the National Institutes of Health. In NIH, according to one critic, one unanticipated consequence has been a "steady deterioration in the value of a progressively greater percentage of experiments undertaken."[45]

The criterion of availability of resources, and a subordinate consideration of program urgency, have been significant in institutional choice in the Defense Department, NASA, and AEC. In these cases, utilization of contractors apparently has provided quicker access to the massive resources required than would have an attempt to build staffs and facilities within government, with all the political and administrative difficulties which government staffing and facility construction interpose. AEC is a particular case in point where the decision to utilize contractor sources hinged on such factors as access to skills, techniques, and personnel; insulation from political pressures; and the ability to match types of organizations with specific tasks.[46]

We have already noted the effects on manpower of the contracting-out process, and we have implied that the nature of the industry involved and its level of on-going technology have greatly influenced institutional choice.[47] The Bell Report has also noted the association of large scale manpower and facility requirements with university-associated research centers, contractor-operated government facilities, and operations in the profit sector of the economy.[48]

The "management considerations" utilized by NASA in making institutional choices are heavily weighted to questions of capability and include the following:

1. Where the best capability is.
2. Whether that capability is really available.
3. The relative cost of each alternative.
4. Urgency, or the need to have a result by a certain time.
5. Whether capability is complete or must be built up.
6. Need to preserve in-house capability.[49]

One other aspect of resource availability should be mentioned. A stated purpose of some research and development programs is the development of additional resources, manpower, and centers of scientific excellence. The Bell Report advocated standards of effectiveness and efficiency "with due regard to the strengthening of institutional resources as well as to the immediate execution of projects."[50] The Department of Commerce has gone on record advocating the utilization of small firms in research and development contracting as a means of upgrading national technological competence.[51]

A major effectiveness and efficiency consideration has been the criterion of flexibility of administrative systems. The practice of contracting out public research and development programs has been justified many times on the grounds that it avoids the inflexibilities, low pay, red tape and other difficulties of civil service operations. The federal establishment's reputation of fixed hierarchies, stuffy attitudes, inflexible personnel policies, and inhibiting ceilings on funds and personnel has been a frequent excuse for extra-mural operations.

We well may question whether this line of argument is compelling reason or merely a justification for a preferred practice. Dr. Donald F. Hornig gave evidence of some belief in the latter when he testified: "An analysis has been made to determine whether the administrative inhibitions found in those [Army, Navy, and Air Force] laboratories have their origin in congressional actions, in civil service rules, or have been self-generated with the individual departments and commands. Most commonly it is the latter."[52] Regardless of whether the so-called inflexibilities of the governmental administrative system are self- or externally imposed, they exist to some extent in reality and to an even greater extent in the minds of government decision makers.

For example, Dr. Gerald F. Tape, then a Commissioner of the AEC, testified that the difference between direct and contractor operated facilities is basically a personnel problem. He compared a civil service system devised for millions of employees in all occupational categories to the AEC's ability to devise personnel policies for mere thousands of employees and specifically for research and development personnel.[53] Certainly, in the early institutional decisions of the AEC, the extra-mural approach was favored for its avoidance of the alleged dampening effects of federal hierarchy on the scientific process.[54]

Other agencies and other extra-mural institutional forms have been influenced by a low opinion of federal in-service processes. The establishment of RAND Corporation and other organizations like it has been viewed favorably as an answer to the problems of public bureaucracy. The opposing view is that such organizations represent a monstrous evasion of civil service and governmental responsibility.[55] The problems are also viewed critically from inside the service as in the National Institutes of Health which maintain a substantial intra-mural scientific operation. The NIH admits to problems of staffing and housing its intra-mural facilities and preserving scientific freedom in the mission oriented operations of a government agency.[56] These problems are real, of course, but the National Bureau of Standards and many other intra-mural government research operations maintain high professional standards of integrity and performance.

The final effectiveness and efficiency criterion has to do with the question of relative cost of the different institutional methods of technological performance. The doctrine of relative cost is contained in Bureau of the Budget Circular A-76 (Revised), August 30, 1967, which sets forth guidelines for cost determination. We suspect, however, that the Bureau's heart is not really in it, for the recent testimony of Phillip S. Hughes, then Deputy Director of BOB, states: "With respect to the factor of cost, BOB Circular A-76 provides guidance for agencies to decide among alternatives on the basis of cost comparisons. However, as was pointed out in Bureau testimony, program requirements and management considerations are the most compelling determinants for choosing alternatives in the research and development area."[57]

The essential problem here lies in the extreme difficulty of arriving at meaningful and valid cost comparisons between private, academic, and federal laboratories. Questions of how to handle capitalization, subsidy, overhead, depreciation, and other matters must be coupled with questions of the valuation of research and development productivity. In such muddy waters, we suspect that cost comparisons can be made to prove virtually anything an agency wishes them to prove. One authority, however, has gone on record with a strong impression that extra-mural operations have cost the government more than would have comparable work done in-house.[58] Verification of this suspicion would be difficult.

E. GOVERNMENTAL RESPONSIBILITY

In a system where substantial government operations are performed by private organizations, where authority is seemingly dispersed, and where responsibility even for policy formulation is unclear, how can the integrity of the system be preserved? The question implies other questions. How can we maintain policy control and fund accountability? How can we judge and choose contractors and laboratories? How should we plan research and development? How can contractors be made responsive to the public interest as defined by the contracting agency?[59] These questions require consideration of the following criteria:

15. <u>Responsibility for Policy Development and Program Planning.</u>
16. <u>A Management Yardstick for Performance Evaluation.</u>
17. <u>Responsiveness to Mission Requirements.</u>
18. <u>Security, Military Support, and Governmental Regulation.</u>

The issue of governmental responsibility and accountability for research and development programs has engaged the attention of many political analysts and not a few critics of the government's emphasis on extra-mural operations. It is not just a question of conflict of interest wherein public policy is made overtly with an eye to private profit, although this is an important issue. The fundamental issue is: Who is responsible and accountable for public policy decisions? After all, the fundamental role of government is to make policy decisions. We may safely contract-out operations but not policy decisions, or so the argument runs. A clear statement of the problem is formulated by Arthur S. Miller:

> Accountability of power, the notion that power must be responsibly exercised, is fundamental in a democratic society. In the contractual system, the problem of discretion in administration, unresolved in the public administration itself, is magnified when power over governmental decisions is turned over to private groups and individuals. . . . In brief, subdelegation of power which is itself almost unrestricted has significant implications for a democratic society.[60]

Perhaps we may safely say of policy decisions and planning responsibilities in research and development the same thing that Gladstone said of budgets nearly a hundred years ago: "Budgets are not merely matters of arithmetic, but in a thousand ways go to the root of prosperity of individuals, and relation of classes, and the strength of kingdoms."[61]

An official statement on this highly significant matter is contained in the Bell Report: "There are certain functions which should under no circumstances be contracted out. The management and control of Federal research and development effort must be firmly in the hands of full-time Government officials clearly responsible to the President and the Congress."[62] Even one of the sharpest critics of the present operations of our federal government, Peter F. Drucker, who insists that government should not directly perform functions, also insists that government must retain and improve its role as the policy decision maker.[63]

But if government must retain its policy and decision making function, at least two difficulties confront us. One revolves around the complexity of the business government is in, the highly technical considerations faced by decision makers, and the real problems of adequate staffing of the government at policy levels. The second difficulty concerns the fact that the operation of scientific programs is not like running a factory. The requirement of technological creativity places certain demands on the decision process. The first difficulty has to do with the institutional methods by which government develops its decisions. The second has to do with questions of centralization and decentralization of policies, programs, and organizational effort. Both dimensions are covered in Charles Hitch's question: "How can we decentralize to promote initiative and spontaneity while maintaining policy control and fund accountability?"[64]

One institutional approach is to centralize the policy, decision, and planning processes within the agency as the Department of Agriculture has done.[65] While this may be possible in a unitary and traditional field such as agriculture, other agencies, Defense in particular, have felt impelled to seek policy advice from outside sources by creating and supporting non-profit "civilian" organizations to provide analysis and advice on a continuing basis. The result has been the creation of the RAND Corporation and other similar advisory private institutions. Some of these corporations, RAND in particular, have assumed missions which include analysis of broad policy issues as a principal task.[66]

Bruce Smith provides an interesting analysis of the comparison between intra-mural and extra-mural provision of policy analysis and planning. To Smith, the in-house method has the advantage of quick response, but he questions whether a single agency can provide a comprehensive enough view. Additionally, bureaucratic pressures can be brought to bear on an in-house analytic group.[67] Advantages of the extra-mural approach include the facilitation of innovation, open channels of communication, and the impartiality and independence of the non-profit institution.[68]

Another approach to the delegation of responsibility to contractors has been followed in the Atomic Energy Commission through an interesting rationale. James Ramey has developed a theory of administrative contract in which the contractor is a "quasi-agent" of the agency. Ramey admits that the AEC "is trying to play both sides of the street in its contractual relations."[69] In any event, in such a "holding company" arrangement, the AEC "calls the signals and provides the top management, but it operates through field offices with non-governmental contractors ..."[70] Another significant element in the AEC situation is the vigorous interest of the Congressional Joint Committee on Atomic Energy which participates perhaps more than any other legislative body in the technological decision making process.[71] Somehow, with all the policy making at headquarters and in

Congress, much in AEC is still left to the local initiative of the contractor operated laboratories. This leads us to considerations of centralization and decentralization.

The Atomic Energy Commission performs a useful function as it searches for a degree of policy unanimity. But policy unanimity and a commission organization are not sufficient to insure the performance of action programs; therefore, the AEC contractors and laboratories are given a high degree of freedom to get the job done without management control. Technical management and the technology itself is entirely up to the contracting laboratory.[72] This is a concept which obviously has been successful in technological terms; however, we now may speculate that the technology has gotten a little too far past the point of the oversight of responsible and accountable government. This may account in part for the AEC's current difficulties with public interest groups in opposition to atomic technology.

Research scientists and engineers like to tell us that effective science can only be carried on in an atmosphere of freedom and independence. Thus, we have noted Michael Polanyi's argument for a republic of science and against the concept of directed, socially relevant research. There may be some truth to the cynic's charge that, as Daniel Greenberg says, "there is, to put it bluntly, a good deal of scientifically nonproductive chiseling that flourishes under the colors of scientific freedom."[73] Be that as it may, the issue of utility versus curiosity must be faced squarely.

Harvey Brooks argues that central management of a scientific enterprise is not effective, that decentralization and diversity of support are desirable; however, he does call for improved long-range planning.[74] Brooks is echoed by Harold Barnett who states unequivocally: "There is a great deal of direct evidence that centralization and strong, detailed, and early programming of military research tend to be less productive of major advances and more costly than more competitive, uncontrolled, and exploratory approaches."[75]

Today, the argument seems to be coming down in favor of more directed research to meet social needs. A recent example is found in NIH where target research and increasing influence of the institutes on research programs have resulted from criticisms of the free and easy methods of the past.[76] The Defense Department has similarly been brought up short by the impact of the Mansfield amendment which reinforces arguments for mission related research programs.

The institutional implications of the criterion of governmental responsibility are fairly clear. Responsibility and accountability for policy, direction, and planning imply strong reliance on in-house capability. As a minimum, capability must be maintained for policy decisions and planning. The maximum is represented by direct intra-mural operations. Utilization of the non-profit sector in the form of a RAND-type corporation has provided a controversial alternative.

The retention of responsibility and accountability within government institutions also implies the requirement for competence to judge and evaluate the results of work performed. In a sharp critique of governmental practices in research and development programs, H. L. Nieburg refers to this function as a yardstick. Nieburg contends that the essential yardstick has in fact been broken and control lost as the intra-mural governmental science facilities have been engulfed in scope and prestige by extra-mural operations.[77] Don K. Price has also raised the question of how the government can administer programs if all the talent is with the contractors.[78] These criticisms and questions highlight the significance of the evaluation function.

The need for federal in-house competence to evaluate programs has been widely recognized. The problem is addressed by the Bell Report which insists that agencies maintain sufficient technical competence so that outside advice does not become de facto decision making. Additionally, agency operated installations are needed to provide sources of technical management personnel.[79] The Bureau of the Budget position is further articulated by Phillip Hughes in Congressional testimony when he describes an important factor to be considered by agencies in choosing institutional alternatives: "The importance of maintaining or acquiring technical competence within the agency to do both an effective job of managing R&D programs and being a sophisticated buyer of the products and services the agency requires."[80]

The necessity of in-house competence has been fully recognized by NASA even though ninety percent of the agency's research and development effort is performed on an extra-mural basis. James Webb describes the basis of NASA's early decisions as follows: "We decided to focus our governmental efforts principally on developing the needed in-house competence to make responsible decisions in every area involved, on organizing and managing, and on ways to test and measure results."[81] The NASA intra-mural emphasis was thus concentrated on spelling out general requirements, evaluating proposals, and judging performance.

A later version of NASA's intra-mural philosophy is described by Harold Finger: "NASA will maintain strong inhouse Civil Service technical competence in order to define our technical goals and objectives and control our technical programs. We will also maintain strong management and administrative competence in order to protect the government's interests, and properly control the expenditure of government funds."[82] Finger describes the relationships of intra- and extra-mural institutions in the NASA program as follows:

> About 90 percent of our budget [is] spent in industry with the in-house laboratory competence providing a technical interface with the contractors to anticipate problems, help guide the contractors to the proper solutions of problems that come up during the development programs. The laboratories are then a very key part of our system for getting the work done, but we do rely very heavily on the available capabilities of industry.[83]

Speaking for the Defense Department, Dr. Donald MacArthur has also testified to the importance of maintaining strong in-house competence. In describing the specialized roles which different institutions play, Dr. MacArthur stresses the importance of intra-mural institutions in maintaining skills for the direction, monitoring, and evaluating performance of the work performed by contractors.[84]

If it has been official governmental policy to maintain a degree of intra-mural technological competence, there has been official concern over the ability of government to do so. The Bell Report notes that the rapid increase of contracting has had a "deleterious" effect on in-house competence. The Report makes specific recommendations that government should "maintain first-class facilities and equipment of its own to carry out research and development work." The Report then proposes several measures of reform to improve the government's intra-mural capacity.[85]

The emphasis in past years on extra-mural operations has if anything increased the need for intra-mural governmental competence in research and development. This paradox is directly related to the government's self-generated difficulty of recruiting sufficient, competent, technologically trained manpower. If government is to discharge its responsibilities, it must maintain control. This was amply indicated by the criticism which fell on the National Institutes of Health recently when a particular extra-mural program apparently abdicated responsibility to the contractor for program review and evaluation.[86] The implication for institutional choice is that government must continue to utilize intra-mural facilities and manpower, and it must maintain its technological operations at a high qualitative level.

The responsiveness of research and development programs to agency and mission requirements is another criterion which has led to an awareness of need for in-house capability. The Bell Report made the point very clearly:

> Direct Federal operations, such as the governmental laboratory, enjoy a close and continuing relationship to the agency they serve which permits maximum responsiveness to the needs of that agency. Such operations accordingly have a natural advantage in conducting research, feasibility studies, developmental and analytical work, user tests and evaluations which directly support the management functions of the agency.[87]

Another view is that of Donald Hornig who looks at the functions of in-house laboratories and finds them particularly suitable for expeditious solution of new problems faced by an agency and for an ability to take quick advantage of technological breakthroughs occurring anywhere in the world.[88]

If intra-mural operations have the advantage of closeness to the agency's mission, extra-mural operations have the disadvantage of increasing remoteness. There is after all a very human tendency for people and institutions to respond most directly to their own immediate goals. A contractor's first loyalty is to his own organization, his profit position, and his reputation. His second loyalty may then be to the objectives of the contract granting agency. Thus, Stephen Toulmin in his article "The Complexity of Scientific Choice" quotes Aubrey Jones: "The doing of research by external agencies is a convenient administrative device for certain purposes at certain moments of time. But the greater use of external agencies the more certain it is that the research will be distant from the purposes of the departments affected."[89]

Finally, two other considerations -- direct military support and federal regulatory activities -- can be included in another criterion which implies intra-mural institutional utilization. For example, the Defense Department policy has long emphasized contracting except in limited instances including projects which are purely military and thus unsuitable for private enterprise.[90] Bureau of the Budget Circular A-76 specifically authorizes direct governmental operation of work which is tied to combat support or mobilization readiness.[91]

The other dimension of this criterion involves work connected with governmental regulation, enforcement, and standardization activities. Again, intra-mural activity is the normal institutional form as in the case of the National Bureau of Standards which has "fundamental responsibility for providing the central basis within the United States of a complete system of physical measurements matched to the needs of American science and industry."[92] This responsibility is joined with responsibility for provision of data on the basic properties of material. In this second function, the Bureau serves as a "scientific service center" for the rest of government.[93] Again, this function has led to intra-mural emphasis; however, the more basic research aspect of this function has also opened the door to some extra-mural activity.

Another example of intra-mural institutional choice in the regulatory area is the Food and Drug Administration which maintains in-house laboratories to carry out its functions of determining the efficacy and safety of drugs and the development of scientific standards relating to "the composition, quality, and effects of foods, drugs, cosmetics, and pesticides."[94]

F. PARTICIPATION AND REPRESENTATION

Public science policy must be responsible and accountable, but to be effective it must also involve the participation and representation of a multitude of organizations, interest groups, and political institutions. Don K. Price states a pragmatic view when he says: "If you want to get something done in a policy field, you get a group of research institutions, allied with a congressional committee and an executive agency, preferably with the support of an enthusiastic economic pressure group."[95] This concept implies a kind of closed circle of interest groups with the general public on the outside looking in. Of late, the look has become more and more hostile to science and technology. We therefore must turn to a fundamental question: How should the general public be represented in the formulation and execution of public science programs? The institutional criteria in this category are:

19. Public and Political Participation and Representation.
20. Scientific Community Participation and Representation.
21. Geographical Parity.

The remarkable success of the scientific community in the last thirty years in expanding its scope and influence has led inevitably to the question: Can science be left to the scientists? Critics of the scientific community answer the question in the negative.[96] Even as accepted a member of the community as Donald Hornig has said: "The shape of science and the directions of scientific progress are no longer a matter for the scientific community alone; they have become part of the public enterprise."[97] This means that a greater involvement of the public and of Congress is required. This also means that non-scientists should have a voice in technological judgments. Another respectable member of the scientific community, Harvey Brooks, has pointed out the fundamentally political nature of technology today and the successful decision influencing role of many lay generalists. Brooks says: "There are times when stating the need for a particular invention without any knowledge of how it can be done technologically may be a much more important step than the technological solution itself."[98]

It is perhaps easy to call for greater public participation in science policy affairs, but it is more difficult to devise institutional mechanisms to achieve this objective. Partial solutions have been applied in some program areas. For example, NASA was well aware of the need for broad support at its inception. James Webb tells us: "In our pluralistic society any major public undertaking requires, for success, a working consensus among diverse individuals, groups, and interests. . . . All large-scale endeavors must be carried on in careful recognition of the necessary participation of legislative leaders."[99] NASA did a remarkable job in developing a broad base of support in the executive and legislative branches of government and in the industrial sector. NASA attempted to do the same, with less uniform results, in the academic world. But, except for an ambitious public-relations program aimed at the public as spectators, the lay public was not appreciably involved.

The leading example of broad public involvement is in the research programs of the Department of Agriculture. For almost a hundred years, agricultural research has been the product of remarkable cooperative venture. There have been close working relationships with states, farmers' organizations, industrial concerns, universities, and research foundations. The result has been a unique blending of national, regional, and local interests which has had exceptional results in terms of agricultural productivity and efficiency.[100]

While most agricultural research is carried out intra-murally, there is significant extra-mural activity conducted through contract and grant programs with state, private, and industrial institutions and firms. Overall research policy is influenced by the National Agricultural Research Advisory Committee. This committee was established by executive order of the President in 1953. Its twenty-five members are appointed by the President. Not more than fifteen are members of one political party; at least eighteen represent farmers; and the membership reflects geographic representation.[101] Through such devices of representation and participation, the agricultural research programs have marshalled impressive political support.[102]

The development of the communications satellite represents another institutional form which provides for substantial citizen participation. COMSAT features private ownership under public regulation, and the corporate board of directors has three of the fifteen directors appointed by the President to represent the public interest. The Communications Satellite Act of 1962 was the final outcome of technical and political rivalries, with the virtues of free enterprise weighing heavily in the original decisions.[103]

Finally, we have noted the unusual participation in AEC policy decisions by the Joint Committee on Atomic Energy in Congress.[104] Subsequent attempts to establish similar joint committees for other technological areas have not been successful in Congress.

The issue of participation of the scientific and industrial communities has been consciously fostered in the planning and conduct of most public science programs. A concept of the scientific adviser has grown up around this issue. The sponsoring agencies have found it natural and desirable to seek the participation of those individuals, institutions, and firms most directly concerned with the fields of technology involved in agency programs. The scientists themselves have wished to participate because participation has given them substantial opportunities to advance their own disciplines and interests.[105] This participation has taken many forms, but the overall effect has been to foster diversity of support, decentralization of decision making, and the utilization of extra-mural institutions for the performance of government technology.[106]

The necessity of broad participation was well understood by the founders of NASA. James Webb has said: "We decided as a matter of deliberate policy to place principal reliance on the entire American industrial establishment and the American University system. . . . We have sought in NASA, with much success, a working partnership between universities, industry, and government."[107] In its origins, NASA was the result of an interplay and conflict between all interested parties, agencies, scientific groups, politicians, and industrial interests.[108] The origin was followed by conscious attempts to broaden the base of industrial and academic participation. Perhaps the ultimate example of NASA's search for participation is the establishment of the Lunar Science Institute which is designed to bring non-NASA scientists further into the space program.[109]

The National Institutes of Health represent perhaps the leading example of involvement of the scientific community in the operation of federal science programs. The participation is secured through the framework of advisory committees, study sections, and the National Advisory Councils which advise and assist the federal managers of the Institutes in decisions regarding review, selection, and funding of extra-mural research projects. The NIH reports officially: "The result of this review process is that the deployment of grant support across the broad range of biomedical problems reflects the consensus of those actually engaged in related research."[110] Herbert Rosenberg brings out another aspect of this process: "Thus, with some significant exceptions, the substantive content of the extramural grant program is <u>not</u> planned. It emerges from the interaction of the research interests of qualified investigators and peer evaluation of scientific merit."[111]

In other words, in medical research, "the scientific community is running itself."[112] This, of course, raises again the question of accountability of government decisions. And it also raises the question of a need to improve the planning and coordination function and to improve the representational structure itself to avoid the solidification of an ingrown circle of advisers who advance their own interests and discourage outsiders. The significance of the role of the scientific adviser in the federal government has been examined closely by Harvey Brooks who sees a "platitudinous consensus" as the greatest hazard of this government by committee.[113] The NIH has responded to such problems by an increasing emphasis on directed research and greater Institute influence over areas of research investigation.

The National Bureau of Standards approaches the question of representation and participation of the scientific community in multiple ways. First, NBS staff members are active in hundreds of professional technical committees and working groups. This is viewed as a means of strengthening NBS programs and activities and of communicating information about the Bureau's work to the outside community. Second, NBS has a statutory Visiting Committee, established by law, and comprised of five prominent representatives from science and industry, which regularly appraises Bureau programs. Third, the NBS has a contract with the National Academy of Sciences -- National Research Council which furnishes a continuing evaluation of NBS programs. The NAS-NRC, in cooperation with professional societies, appoints advisory panels of technical experts who provide guides in the formulation and execution of the Bureau's work. These panels also serve as a link between the NBS and the scientific community.[115]

A relatively new issue of geographic representation has arisen to confront federal decision makers. Federal expenditures for technology have been greatly beneficial primarily to the northeast and west coast regions of the United States. Funds have tended to flow to those regions and institutions with the greatest established competence, and as a result the rich have tended to get richer while those regions and institutions with lesser staff, facilities, and reputations have been relatively neglected. This phenomenon persisted until it ran into the old American tradition of political regionalism. The politics of geographic distribution now represent a significant criterion for institutional choice.[115]

One result has been a National Science Foundation program for the development of additional centers of excellence. This program deliberately allocates funds to universities with the dual objective of obtaining quality research results and strengthening the scientific program of the grantee. The Defense Department's Project Themis has had a similar orientation.

Another manifestation of geographic representation has been the development of regionally based associations or consortiums of universities to participate in large-scale federal technology programs. Finally, consideration of the location of federal in-house laboratories and the allocation of funds and projects are frequently conditioned by geographical location. Geographical parity as a criterion of institutional choice could, of itself, do much to alleviate existing geographic imbalances in the expenditure of federal funds for research and development.[116]

G. EDUCATIONAL CONSIDERATIONS

In Michael Reagan's priorities framework, he ranks science-related educational needs second only to social needs.[117] This is a fair indication of the general realization, implicit or explicit, in many federal science programs of the vital importance of developing and maintaining an adequate base of scientific manpower and institutional competence for research. The institutional criteria are:

22. Scientific Manpower Training and Development.

23. Educational Institution Development.

In the last decade the federal government has maintained an official policy of encouragement and support of the education of scientists and engineers. This policy is part of the government's recognized need not only to perform or obtain technological program results but also to "maintain and enlarge the long-term strength of the Nation's scientific resources, both public and private."[118] The policy has been expressed in part by direct assistance programs to students. More importantly, substantial support of educational programs has come in the form of grants in support of university-based research projects which in turn have provided financial and facility support for students. In addition, federal policy has strongly encouraged government laboratory facilities to be located in the proximity of universities.[119] Such co-location is advantageous for both parties in terms of use of facilities, joint projects, the use of federal facilities as training sites for students, and the facilitation of continued education for federal scientists.

An additional thrust of the federal policy toward educational institutions has been the objective of strengthening the institutions themselves, through the mechanism of institutional grants as opposed to specific project grants. The government has deliberately followed policies of supporting scientific excellence where it is found and also of supporting the development of additional centers of excellence.[120] The institutional support of individual universities has been viewed as necessary to basic research and also to the maintenance and development of national scientific capability.[121]

The NASA program offers a prominent example of an agency's evaluation of multiple criteria in reaching decisions to utilize academic institutions. As Wesley Hjornevik says: "The intent of those who envisioned space flight was not simply to pursue and complete a project; rather, it was to build a solid baseline of advanced technological competence in the United States."[122] A central concept of this intent was the use of universities to provide basic research and also to produce trained manpower. The institutional realization of the concept was obtained by not pulling researchers away from the universities but by leaving them there and supporting them in mutually interesting and significant projects.[123]

The net effect of the government's support of academic institutions has been a remarkable growth in size, prestige, funds, facilities, and faculty of the technological departments of colleges and universities. However, there is no evidence that massive federal support of academic science has increased the proportion of student enrollment in the sciences and engineering, nor has it served to concentrate the best and brightest students in the technical disciplines.[124]

H. TWO OTHER CRITERIA

For convenience we are joining two essentially dissimilar criteria together in one general category. The first, technology transfer, is an objective still imperfectly understood and achieved. The second, past practice, is perhaps one of the most influential of criteria which might appear under the less complimentary name of organizational inertia.

24. Technology Transfer.

25. Past Practice.

The problems of achieving rapid diffusion of knowledge horizontally through the public and private sectors and vertically through the scientific disciplines invoke substantial considerations of institutional choice. The essential problems of technology transfer have been identified by Harvey Brooks as related to the standard organization of government and industry for vertical transfer from science to product or mission, and the failure of government and industry to develop institutions to apply technology horizontally across public and private sectors in such problem areas as pollution, transportation, and medical technology. Brooks speaks to these problems with two recommendations:

> Federal policy should include a purpose of fostering the rapid diffusion of the technology induced by government research and development, and consideration of the economic impact of government R and D.
>
> . . . .
>
> In order to foster horizontal in addition to vertical transfer of technology large broad spectrum federal research institutions should regard it as part of their function to market new technologies to other federal agencies and missions and to institutions in the private sector.[125]

The government has made some attempt to meet these problems. The State Technical Services Act of 1965 established a technology transfer function within the Commerce Department. This somewhat controversial operation was apparently achieving some success when its appropriations were terminated by Congress for fiscal year 1970. There is hope that the function will be resumed perhaps in the form of an industrial extension service patterned after the Agriculture Department's extremely successful agricultural extension service.

Other agencies including the Departments of Transportation and Housing and Urban Development have specific organizational units charged with responsibility for technology transfer, and the Commerce Department operates an information service under the title of Clearinghouse for Federal Scientific and Technical Information.[126]

Perhaps the most energetic such effort is NASA's technology utilization program which has recognized the significance of technology transfer as an essential support for the space program. The concept of "spin off" technology was applied early in NASA's history, perhaps in anticipation of the latter day criticism of the space effort as being socially non-utilitarian. The attempt of NASA and other agencies to foster technology transfer by utilization of an in-house organizational unit clearly demonstrates one institutional method of achieving the dissemination of research and development results for broader application.

The NASA experience also illustrates another institutional method of achieving technology transfer -- that of utilization of private contractors and universities in the performance of research and development. Harold Finger's comment on this subject is appropriate:

"Through the project activities in universities and industries we believe that the process of having that work done in those institutions [means that] they can apply the technology to other activities that they have in all areas."[127]

The validity of Finger's belief and of Brooks' analysis of the vertical organization of technological effort was demonstrated earlier by a Denver Research Institute study of the commercial application of space technology. DRI discovered that technology transfer occured most easily within the same organizational unit in which the innovation was developed, and that technology flowed to other organizations and other sectors with difficulty and only with the intervention of some middleman device. DRI's summary states:

> There are apparent gaps between the persons or organizations responsible for developing missile/space technology and those persons or organizations which can give such technology commercial application. However, market requirements information must be linked with missile/space technological knowledge before commercial applications can occur. Linkages between market information and technology appear to take place more easily inside a single division of a firm than between separate divisions or separate firms. A few mechanisms for bridging these gaps between organizations with missile/space technology and other organizations with commercial marketing capabilities have been established and their effectiveness in facilitating linkages is worth investigation.[128]

Turning now to the consideration of past practice, we find this to be a criterion which has a powerful influence on institutional choice and which is often taken for granted. The inclination to preserve an ongoing facility or program at an equal or greater level of ongoing budget support is strong indeed.[129] This is not to say that changes never occur. The research orientations of Public Health Service and the Army and Navy

Departments were strongly intra-mural during the 1930's, but they switched dramatically to extra-mural program emphasis during the 1940's and in subsequent years. The in-house inclination of NACA changed to the ninety percent extra-mural emphasis of NASA. The Departments of Agriculture, Commerce, and Interior all have moved slowly toward greater emphasis on extra-mural activities, while the Veterans Administration, interestingly enough, has moved in the opposite direction.[130]

The dramatic changes occurred during World War II when great program demands were coupled with severe manpower shortages within the federal service. Most changes in program emphasis, however, occur incrementally; and barring crises, emergencies, and overwhelming public outcry, we may safely speculate that innovation by any agency in matters of institutional choice will be slow and gradual.

The fact that past practice is such a strong influence on institutional choice indicates that the criterion should be brought out into the open and analyzed for what it is. In their discussion of this factor, Elmer Staats and William Carey make a strong point for openness of consideration and for ignoring sunk costs in arriving at decisions about future programs.[131]

I. CONCLUSION

It would seem that the only universal criterion for institutional choice is that individuals and agencies will be different, that we Americans will be pluralistic, inventive, competitive, individualistic, and perhaps chaotic in our institutional arrangements. Every institutional form has in some way met a range of criteria, and all the criteria we have discussed (and undoubtedly others) have been used in some degree by one or more agencies in arriving at their choices. It now remains for us to display in concise, graphic, and tabular form the general relationships of institutions, criteria, and choice, and then to examine the requirements of the minerals sector in relation to the most appropriate criteria.

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CHAPTER V

THE CRITERIA MATRIX

Before proceeding to a discussion of criteria for institutional choice for performance of minerals technology programs, it may be useful to recapitulate the discussion of the preceeding chapter in summary form. A summary matrix display, figure 6, contains the twenty-five criteria discussed above arrayed in relation to the eight principal types of institutional mechanisms for the accomplishment of federal science programs, as defined in Chapter III.[1]

The matrix permits, in a very generalized way, an identification of the predominant utility of each kind of institutional alternative. A strong degree of utility is indicated in the matrix with the symbol "X". This generalized approach, as demonstrated in figure 6, is based on the preceding discussion and is intended to be primarily illustrative. Any individual agency might well arrive at a different weighting of utility for each institutional alternative in relation to each criterion as conditioned by the specialized nature of the agency's program.

Some version of the criteria matrix lies at the heart of the decision process leading to institutional choice. The matrix serves as a summary representation of the variables which influence decisions. As such, it can serve as a tool for analysis, understanding, and weighting of the multitude of influences which bear on any single institutional decision. Use of this tool will serve to increase the openness, rationality, effectiveness, and objectivity of institutional decisions.

CRITERIA	National Laboratories	Industrial Contractors	Universities & Non-Profits	University Consortiums	Univ.-Gov't Cooperatives	Bridging Institutions	RAND-Type Institutions	Public/private Corporations
NATURE OF THE PROGRAM								
1. Basic Research			X	X	X	X		
2. Exploratory Develop.	X				X	X	X	
3. Advanced Development	X	X						X
MERIT OF THE PROGRAM								
4. Scientific Merit			X	X		X		
5. Technological Merit	X				X		X	
6. Social Merit	X	X					X	X
PUBLIC/PRIVATE INTEREST								
7. Private Enterprise Values		X	X					X
8. Public Sector Technology	X	X			X	X	X	
9. Private Sector Technology	X	X			X	X		X
10. High Risk and High Cost		X		X				X
EFFICIENCY AND EFFECTIVENESS								
11. Competition		X				X		
12. Resource Availability	X	X		X	X	X		
13. Flexibility		X	X	X	X	X	X	X
14. Relative Cost	X				X			
GOVERNMENT RESPONSIBILITY								
15. Policy Development						X	X	
16. Management Yardstick	X				X			
17. Responsiveness	X						X	
18. Security and Regulation	X					X	X	
PARTICIPATION								
19. Public Participation						X		X
20. Scientific Community				X	X	X		
21. Geographical Parity			X			X		
EDUCATION								
22. Manpower Training			X	X	X			
23. Institutional Development			X	X	X	X		
OTHER CRITERIA								
24. Technology Transfer		X	X	X	X	X		
25. Past Practice	X	X	X	X	X		X	

A high degree of applicability of criteria to institutional form is indicated by the symbol "X".

Criteria Matrix for Institutional Choice

Figure 6.

In this, we take the position of Howard and Morgenroth who believe of the decision-maker "that largely to the extent he fully articulates his view (constructs a model) of this decision process he will be effective in carrying out his task."[2]

In questions of institutional choice, the decision-maker is confronted with relatively flexible situations featuring a low degree of objective data and requiring a high degree of subjective evaluation. The basic operational mode of the decision process is one of a comparison of given situations and data with a wide variety of standards, values, objectives, images, aspirations, organizational procedures, and some objective information. Decisions resulting from this comparative process are represented by institutional choice.

It now remains for us to apply such a decision process to the requirements of national policy for the minerals sector.

FOOTNOTES for CHAPTER V

1. See above, pp. 41-48.

2. John A. Howard and William M. Morgenroth, "Information Processing Model of Executive Decision," Management Science, XIV (March, 1968), 416.

CHAPTER VI

INSTITUTIONS FOR MINERALS RESEARCH

As we have indicated in Chapter II, an adequate supply of mineral resources at a reasonable cost is a fundamental element in the strength of the general economy and, therefore, in the national interest. Assurance of a future long-term adequacy requires a general upgrading of technological effort, both in quality and quantity. The market process is not providing sufficient technology. Neither are government and the universities in their present programs. But any kind of improvement will require the involvement of government, industry, and the universities if the challenges are to be met.

A. THE NEED FOR POLICIES AND PARTNERSHIPS

A large scale technological effort requires a coordinated effort — the kind of mobilization of industry, universities, and government which has been so successful in the fields of atomic energy, space, and health. The need for this kind of partnership in the minerals sector has long been recognized in the Department of the Interior, but the institutional mechanisms for establishing the partnership have not been established.

Many reasons may account for the failure of the partnership to materialize. It may in part be due to a general lack of recognition within the federal government of its role in supporting private sector research and development in areas, such as minerals, where the market process does not produce sufficient technology.[1] Another reason has to do with institutional inadequacies. The required machinery for co-ordination of all relevant interests has been lacking, and traditional bureaucratic forms have been inadequate.[2]

Also lacking, as we have noted, have been adequate statements of purpose, objectives, and policies of government in regard to minerals. The direction of needed institutional change must be predicated on a clear understanding of the purposes to be achieved. Both ends and means must be considered. The inadequacies of policy and objectives in minerals technology can be demonstrated by comparison to other federal programs. In the Defense Department, NASA, and AEC, an aggressive pattern has been followed:

> "The decision makers in these programs chose not to wait passively until research and development had been undertaken by others. They decided to engage upon a deliberate search for new ideas and new technology. . . . They have attempted — and successfully — to bring the resources of science and technology to bear . . . and they have melded the efforts of scientists, engineers, industry, and the Government in the task."[3]

There are signs that the government is beginning to take its responsibilities for minerals policy and objectives more seriously. The Senate hearings in 1963 and again in 1969 brought forth official calls for partnership, new government initiatives, and greater attention to these matters.[4] In 1968, an aggressive Director of the Bureau of Mines pointed out:

> In our political and economic system, it is the responsibility of private industry to develop and exploit resources to meet demands of the market place. It is the federal government's role, however, to assume a position of leadership in determining the projected needs, in supplying the long-range scientific and technologic support for the minerals industry, and in using techniques such as education, communication of

> information, and cooperation to encourage industry to attack the vital problems of minerals supply. Such assistance is especially necessary where the risks are too costly to be undertaken by a corporate entity, and where the rewards benefit the public rather than a particular industry.[5]

Perhaps the most promising indication of new developments in government is contained in the recent statement of Lee DuBridge to a Senate committee:

> We envision that the Department of the Interior would take the lead in identifying the areas where research and development of new technology would be most useful. While this first step would be conducted or funded by the government, its purpose would be to guide industrial and university efforts as well as subsequent government work. In cooperation with the Bureau of Mines, we have recently contracted with TRW, Inc., . . . to develop an R&D plan for underground coal mining. This is really an experiment to ascertain how advanced technologies and methods can be applied to a particular segment of the mining industry and, hopefully, may provide a model for Interior's subsequent efforts on other minerals problems.[6]

The burden of every argument is for greater partnership. Private authors have made the point forcefully; state governments have recognized the need; Congress has made a case for the partnership; and present Interior Department leadership has taken a stand for greater inter-sector cooperation.[7] It would seem that we are close enough to unanimity of opinion, close enough to the statement of policy, that we may now turn our attention to institutional mechanisms for achieving the partnership. The culminating objective in the remaining pages is to suggest an institutional framework for policy decision as well as program operation in the minerals sector. In drawing up a blueprint for an institutional design, we will look first at the criteria for institutional choice which are relevant to minerals technology.

B. MINERALS AND INSTITUTIONAL CRITERIA

In developing an effective approach to improved minerals technology, the first questions refer to how it should be done and by whom. What will meet the peculiar requirements of the minerals problem? The discussion in Chapter II brought out many considerations. We propose now to relate those considerations to specific criteria.

1. Nature of the Research and Development Program.

The technological challenge of minerals research required in the public interest tends to be of an exploratory and advanced development nature. There is some continuing requirement for basic studies, as has been pointed out by Walter Hibbard.[8] However, the principal problems are not in the realm of fundamental or basic science. This point was made clearly by the Paley Commission:

> Few of the demands made upon technology by the minerals problem lie in any realm of high scientific difficulty. The problem lies elsewhere — in costs. . . . The all-embracing problem for technology in the materials field is to insure a steady, concentrated flow of materials, rich in diversity, at costs which will make possible their wider and wider utilization. The wonders of science are not at issue here; what is at issue is the hard facts of economics.[9]

The institutional implications of this are that assignment of programs to national laboratories and contracts with industrial firms will provide the most likely sources of minerals research competence. Other possibilities could perhaps include university-government cooperative enterprise where the university department concerned is oriented to applied research as in the case of engineering departments. A public/private enterprise is appropriate for applied development, but the minerals sector lacks the unity of objective or industry structure which characterized the communications industry in COMSAT.

2. Merit of the Research and Development Program.

Considerations of merit share similar implications with the nature of the program. The principal objectives of publicly supported minerals research are to secure technological improvements for the achievement of the social goals of maintaining adequate supplies of needed minerals at acceptable costs. Again, the institutional implications lean to national laboratories and industrial firms.

3. A Calculus of Public and Private Interest.

The doctrine of free enterprise has not been applied consistently in terms of governmental support of technological development. While there has been no hesitation on the part of government to have research performed by private industry in aerospace, defense, and communications, there has been little inclination to do the same in the minerals sector. We are perhaps faced with a national or public feeling about "clean" industries versus "dirty" ones, new industries versus old, and other such value judgments. We have noted that it was only in 1966 that the Bureau of Mines was able to obtain authority to contract-out minerals research and development projects.

In a sense, this may be a reverse twist on the free enterprise argument. If, as John Gray has pointed out, the economic operation has been dominant in determinations about materials technology, then we are truly expressing free enterprise values.[10] This leads us possibly to the origins of the debate between Senator Anderson and Dr. Hibbard regarding the propriety of funding technology which benefits private industry.[11] Some light is perhaps now shed on the paradox of the government's inclination to buy technology from extra-mural sources for public sector programs, while it has the reverse tendency to perform in-house that research which benefits the private sector.

This brings us face to face with the institutional implication. We have suggested that minerals research has a prominent public utility aspect even though the immediate beneficiaries are in the private sector of our economy. In such an intertwined and complex environment of public and private benefit, logic drives us to a conclusion that research which has substantial benefit for a private sector should be performed substantially in the private sector with government support. This line of reasoning also supports another desirable objective of minerals policy — that of increasing technological competence and activity in the private minerals sector.

This is not to say that the long-established and well-developed intra-mural capacity of government for minerals research and development should be abandoned. The establishment by responsible public officials of effective national minerals policy requires technological data as well as economic and social information. The technological support of policy determination is a public sector function well suited to government laboratories.

We have ample precedent for mixed public/private effort where benefits accrue to both sectors. For example, the House Committee on Government Operations has noted:

> In farming, it was clear to the Federal Government from the 19th century onward that the fragmented nature of farms would not encourage private R & D. In health and medicine, during the 1950's and 1960's, the Government has acted on the

> assumption that community benefits from increased research would be substantially greater than the value accorded such research by individuals as such. In civil aviation, the Government has taken into account the inability of even large private firms to assume the high risks and huge costs of major forward leaps in technological development.[12]

If this is not sufficient justification for additional extra-mural effort, we may turn to the Paley Commission which made clear its belief in private enterprise as the "most efficacious way of performing industrial tasks in the United States."[13] And of course we may also call on the Bell Report and Bureau of the Budget Circular A-76, as previously noted.[14]

Considerations of high cost and high risk technology in the minerals sector implies the necessity or desirability of government support. As John Gray says of minerals research: "Research of the kind suggested here ought to be done mainly by the industries concerned; but as most of it will not yield an early return, industry will be reluctant to undertake it."[15] The institutional implications of this criterion revolve around the requirement of large scale resources, and this requirement implies combined efforts and marshalling of resources. In the minerals industry in particular and in others like it where profits are low, the industrial structure is fragmented, and where technological development is extremely costly, special programs are required. J. Herbert Hollomon has addressed this need:

> "We need to create a means for encouraging associations of companies and industries to do technical work that benefits them as a group when it is too costly and wasteful to carry on the work separately. . . . An industrial analogue of agricultural extension education is required, and it is the responsibility of government, both local and federal, and the universities and industry to establish it."[16]

4. Efficiency and Effectiveness.

The question of how to develop effective institutional resources for minerals research is best attacked on the basis of incentives. We have noted Harvey Brooks' call for indirect incentives rather than direct subsidy of research and development. His argument is that through use of indirect incentives, the market process can be approximated and the public itself thereby involved.[17] This view has the merits of maximum use of market processes, but indirect incentives such as tax advantages lead to charges of favoritism for specific industries. If the reduction of the depletion tax allowance for the oil industry can be taken as an augury, such incentives may be hard to come by in the face of public opinion regarding special privileges for those industries which have unfortunate environmental side effects.

Another approach to quasi-market mechanisms is through the means of competition between institutions for research support. This appears to be a promising methodology of institutional choice which could contribute to the effectiveness of performance and also to the generation of additional capacity in the private and academic sectors. The use of "imaginative rivalry" has been cited as a means of improving innovation in Defense Department supported technology.[18] Charles Hitch's original concept of competition implied the effective rivalry between industry and between governmental agencies.[19] In the present structure of minerals technology, competition between government laboratories, private companies, and university research interests for government supported and funded research programs could have beneficial long-term results. In today's minerals sector, another possibility -- the small firm -- should also be encouraged and supported as a source of technological development. This is argued officially by the Commerce Department, and a good economic analysis of the use of small firms is presented by Daniel Hamberg.[20]

A critical determinant of institutional choice is the availability of qualified manpower and adequate facilities. We have advocated competition as a means of upgrading all resource sectors. Below, we will look to educational programs for long-term provision of necessary manpower resources. But in the present situation, the mineral industry is characterized by a relatively low level of technological effort, which implies an inadequate resource base. The intra-mural activities of government, on the other hand, provide a solid base of technological competence, thus reinforcing the necessity of continuing intra-mural activity. The relatively low level of technological activity in the minerals industry indicates the need not only for government support of research and development, but also for institutional forms of cooperative effort as in the case of agriculture.[21] A small scale example of cooperative effort in the minerals sector has been in bituminous coal research sponsored by the Bureau of Mines, Office of Coal Research, and the coal industry.[22]

We are not addressing the criteria of flexibility and relative cost. All systems of organization have built-in inflexibilities. Research and development can be accomplished efficiently and effectively by Civil Service employees and by contract personnel, by academic scientists and by the staffs of non-profit corporations. Questions of relative cost are at this point incapable of elucidation to anyone's satisfaction. Decisions regarding institutional form are best made on other grounds.

5. Governmental Responsibility.

The basic functions of government in the minerals sector include regulation of certain aspects of industrial activity, most notably environmental protection and health and safety of workers, and development of information necessary for policy decisions. If there were a substantial increase in extra-mural activity, the function of evaluation of contract or grant performance would assume greater proportions.

Each of these functions implies maintenance of the strong intramural capacity which presently exists in governmental agencies. Alternatives to intra-mural operations conceivably could include creation or utilization of an advisory corporation such as RAND, or creation of an impartial bridging institution to stand between government and the private and academic sectors.

6. Participation and Representation.

In the American social context, the most significant criteria are not really connected with efficiency as much as with a process of government which involves multitudes of interests and people. In devising new institutional forms for the technology required to accomplish new social objectives, we need to keep uppermost in mind the importance of participation and representation. By participation and representation we also must mean a broader public, a larger sense of national interest than we can obtain from just those private and public participants in a closed system. In considering institutional choice, and in applying criteria of choice, we are required by the needs of our time to emphasize those criteria pertaining to participation and the selection and development of institutions appropriate to those criteria.

In a recent study of the innovative process, the National Academy of Engineering reaches a conclusion supporting the significance of non-technical processes: "There appears to be general agreement that the process of successful technological innovation depends on many more factors than the mere generation of scientific and engineering information. . . . Gaps, if they exist, appear to be in the understanding of social and environmental factors that influence management and government decisions."[23]

Many of the environmental issues surrounding the minerals industry have created substantial public interest, controversy, and outcry. The public is becoming increasingly involved in these issues, but the public has no effective method of participation in policy formulation and decisions. We have noted the urgent need for full participation of all segments of the minerals sector, and in particular the scientific community, in an attack on the problems of minerals. To this we must add the participation of the broader public. But again, effective means for a fully coordinated effort do not presently exist.

Participation and interaction between government, industry, and the universities is not adequate. For example, William Harris draws attention to the unfortunate degree of separateness existing between the Bureau of Mines and the minerals industry. This separateness exists in the face of real problems of technology, economics, and environment. In 1963, the Federal Council for Science and Technology made "a forthright plea . . . for greater cohesiveness in industrial research on minerals and much closer cooperation between industry, universities, and federal agencies."[24] The FCST also advocated a broader, ecological perspective and an interdisciplinary approach to solving minerals problems.[25]

The formulation of public policy conventionally is the result of a complex process of bargaining, interaction, maneuvering, and brokerage in the midst of a whirlpool of interest groups, each represented in some way in the decision process.[26] In the minerals sector, this political process is poorly coordinated, for the process is as fragmented as the industry, and there is no suitable arena for the interaction. Additionally, as in most American political processes, there is a substantial problem of the process reflecting the outcome of interest group interaction but not considering any larger issues of public interest and the total constituency.

The institutional implication of this is that some device must be found to improve the participation and representational processes in the making of mineral policy and the conduct of minerals research programs. We may look to many examples developed over the years in federal technology programs of institutions for the representation and participation of the scientific community. These include the use of advisers, consultants, study sections and peer evaluation panels, and cooperative and joint enterprises. Unfortunately, the scientific community in general and the governmental science/policy relationships in particular have not yet evolved institutional mechanisms for the representation and participation of the larger public.

7. Educational Considerations.

The need for upgrading the minerals education process, both from the standpoint of students and of institutions, has been widely discussed and documented. However, because of the applied and developmental nature of most minerals research programs, the universities are less appropriate institutions for the conduct of minerals research. Yet some way must be found to support minerals education, for the long-term need is critical. As Brown, Bonner, and Weir have pointed out:

> We are immersed in a technical age which feeds upon technical brainpower. If we wish to produce more and more goods for more and more people from ores of lower and lower grade, then we must find the technical brainpower to develop the essential knowledge and to apply it with the necessary skill and diligence. Only in this way can a highly industrialized nation continue the development which is necessary to its maintenance.[27]

We have noted that in some federal programs requiring large-scale facilities, universities and consortiums of universities have become involved as sponsors, managers, and operators of applied and developmental programs. This would appear to be an appropriate method to obtain university involvement and to add to university incentive for support of minerals programs without impinging or diluting the university's primary function of education.

8. Other Criteria.

There is obviously little use in governmental support for technological development in the minerals sector if such technology does not become quickly and widely diffused. As noted previously, technology transfer is improved through the utilization of private contractors and universities in the accomplishment of federally supported research.

When intra-mural facilities are used, as in the Bureau of Mines and the Bureau of Standards, an institutional device is required for the dissemination of technical information.

The criterion of past practice implies continuance of the government's major emphasis on intra-mural operations in minerals research. Any depletion of the existing technological resources within government would be most unfortunate, because these resources represent the major organized and coherent source of minerals expertise. What we are saying essentially implies full use of existing intra-mural resources plus use of additional sources for technological effort. This in turn implies a higher level of total funding for minerals research on a government-wide basis. We should then regard existing government facilities as a base to be improved qualitatively, if possible, but not quantitatively. Program increases should by this argument be diverted to extra-mural operations.

In summary, the above applications of institutional choice criteria to the minerals sector are displayed in figure 7. The implicit reasoning in the display will then be translated into statements of institutional requirements and recommendations.

C. THE INSTITUTIONAL REQUIREMENTS

The political, social, economic, and even technological trends of today indicate that the most significant grounds for decision seem to be matters of participation and representation in the vital affairs of the nation. Such grounds are no less significant in the minerals sector. Concepts of participation and representation will enable the mobilization

CRITERIA	National Laboratories	Industrial Contractors	Universities & Non-Profits	University Consortiums	Univ.-Gov't Cooperatives	Bridging Institutions	RAND-Type Institutions	Public/private Corporations
NATURE OF THE PROGRAM								
1. Basic Research			X					
2. Exploratory Develop.	X			X		X		
3. Advanced Development	X	X						
MERIT OF THE PROGRAM								
4. Scientific Merit			X			X		
5. Technological Merit	X	X		X				
6. Social Merit	X	X						
PUBLIC/PRIVATE INTEREST								
7. Private Enterprise Values		X						
8. Public Sector Technology	X							
9. Private Sector Technology	X	X						
10. High Risk and High Cost		X		X				
EFFICIENCY AND EFFECTIVENESS								
11. Competition	X	X	X			X		
12. Resource Availability	X	X	X					
13. Flexibility								
14. Relative Cost								
GOVERNMENT RESPONSIBILITY								
15. Policy Development	X							
16. Management Yardstick	X							
17. Responsiveness	X	X						
18. Security and Regulation								
PARTICIPATION								
19. Public Participation	X							X
20. Scientific Community			X	X		X		
21. Geographical Parity								
EDUCATION								
22. Manpower Training			X	X				
23. Institutional Development			X	X		X		
OTHER CRITERIA								
24. Technology Transfer		X	X	X		X		
25. Past Practice	X							

A high degree of applicability of criteria to institutional form is indicated by the symbol "X".

Criteria Matrix for Institutional Choice in the Minerals Sector

Figure 7.

of academic and industrial sectors to meet technological challenges. They will enable the marshalling of public involvement in finding solutions to problems affecting the environment and still preserving the productivity base of the industrial society.

These considerations lead to our recommendation that all sectors of our economy be utilized in meeting the technological problems of minerals. Implementation of this recommendation will require establishment of a new research and development institution within government. This is not a radical recommendation. We are merely responding in a specific way to the earlier recommendations of the Bell Report which called for the creation of a new kind of research and development institution.[28] In a sense we are echoing Bruce Smith who views institutional arrangements as the logical focus for national program planning debates, and who has recommended the institutionalization of the interplay between public and private initiatives.[29] The recommendation responds to criticisms by Meg Greenfield and others of scientists who seek freedom from public scrutiny as they plan and conduct national science policy.[30] Finally, the recommendation responds to the new concepts of William McElroy and the National Science Foundation and their call for new institutions which will make science more responsive to social needs.[31]

If the technological decisions and evaluation processes are made institutionally open to the scrutiny and impact of representative government and public participation, the dangers of loss of accountability and responsibility are lessened. The prospects of responsiveness of federal technological programs to the public interest are heightened.

Some years ago, the Resources for the Future staff made several recommendations to the Interior Department on how the Department could meet the challenges of mineral resources depletion. Included among the recommendations was a very modest proposal for the establishment of scientific and technological program review groups, including the representation of non-scientists acquainted with resource problems.[32] This modest proposal was not directly implemented, but now we need to incorporate this idea into a new, far reaching institutional form within the Interior Department.

D. RECOMMENDED: A NATIONAL INSTITUTE OF MINERALS RESEARCH AND DEVELOPMENT

The present planning and operation of governmental programs in minerals research and development is through a multitude of agencies with little coordination and no single focal point of polity or evaluation. We are recommending that this pattern of particularism and uncoordinated activity be pulled together and given focus through the institutional mechanism of a National Institute of Minerals Research and Development (NIMRAD).

This recommendation is not new. Eighteen years ago the Paley Commission came to a similar conclusion and proposed the establishment of a single agency "to keep track of public and private research affecting production and use of materials in light of current needs and future prospects, and to make sure that urgent research projects which industry could not be expected to undertake were referred to public or private organizations capable of carrying them out."[33] The Paley Commission proposal was for an agency which would be a part of the President's Executive Office and which would have informational, appraisal, evaluational, and auditing responsibilities. The recommendation was not implemented.

In 1959, the Federal Council for Science and Technology established an Interagency Coordinating Committee on Materials Research and Development. The committee was composed of representatives of AEC, Defense, NASA, NSF, NBS, Bureau of the Budget, and the Bureau of Mines. This committee established a program of interdisciplinary laboratories for materials research by contract with twelve universities. An equipment grant program was established in seventy-nine universities.[34] The concept of the Committee on Materials Research and Development is a direct forerunner of the recommendation for NIMRAD, carried to a much further extent.

Similar institutional proposals have been advanced in areas of biology, urban development, and oceanography; and a recent proposal has been made for the establishment of a government-wide National Institute of Technology.[35] While these proposals have remained in the idea stage, a more concrete example of action along the recommended lines came in 1968 with the establishment of the National Eye Institute. This Institute followed the example of previously established institutes within NIH. The purpose of the National Eye Institute is "to provide a clear focus for the efforts of those interested in eye research."[36] This purpose is implemented within the Public Health Service, and the operations of the Institute are influenced by an advisory council. In this, the National Eye Institute has followed the lead of the pioneering National Cancer Institute, established by legislation in 1937, which enabled the government "to join in common purpose with the nonfederal scientific community in the support of research activity of broad public interest."[37]

The establishment of NIMRAD along the lines of the National Eye Institute would provide a linking mechanism between technological means and social ends in the minerals sector. It would also serve as a focal arena for participation and representation in the decision making process of government, industry, the scientific community, and the citizenry. These interrelationships would provide opportunity for the further linking of basic and applied research to political goals as revealed through representative political processes and to national objectives as developed through governmental planning and budgetary processes. The conceptual relationships of NIMRAD are illustrated in figure 8.

The specific institutional format recommended for NIMRAD, in keeping with the relevant criteria for institutional choice, includes the following elements:

1. Objectives. The principal objective of NIMRAD would be to insure the adequate and dependable flow of minerals and fuels, to meet national needs at a reasonable social and economic cost, consistent with the requirements of an expanding economy and the national defense. A secondary objective would be to increase the minerals technology capabilities of government, industry, and universities, and to marshal these capabilities in a concerted attack on the minerals problems facing the nation. Additional objectives would include enlisting the public in the task of finding solutions to minerals problems, and giving priority attention to solving environmental problems created by minerals extraction and utilization.

FUNCTIONAL RELATIONSHIPS OF THE NATIONAL INSTITUTE OF MINERALS RESEARCH AND DEVELOPMENT (NIMRAD)

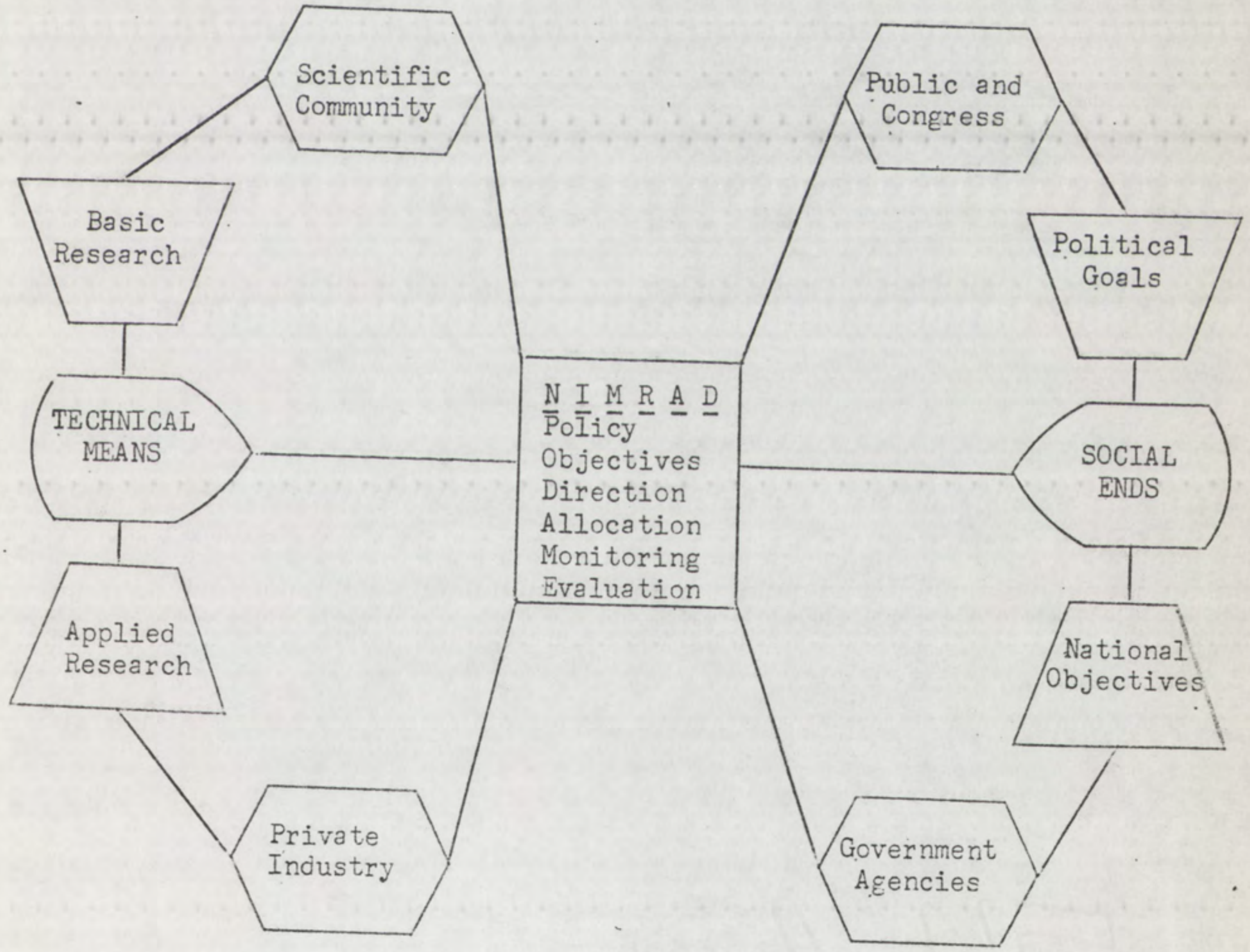

Figure 8. Functional Relationships of the National Institute of Minerals Research and Development (NIMRAD).

2. Establishment. The establishment of NIMRAD would be a logical addition to Senator Allott's proposed legislation to establish a national minerals policy. NIMRAD would provide the needed action element to oversee policy implementation.

3. Organizational Location. In order to assure maintenance of full governmental responsibility, NIMRAD should be located fully within the federal governmental structure and specifically within the Interior Department which has primary responsibility for mineral resources and environment. Location within an executive department insures a degree of responsiveness of a government institution to the will of the people as expressed through the electoral process.

4. Implementation. The implementation of NIMRAD should be in three stages. First, appointment of an executive director and a representative board of directors to begin advising on policy directions and resource allocations. The first stage is regarded as minimum implementation. The second and third stages could include the incorporation of existing governmental activities and the eventual construction of physical facilities. NIMRAD could eventually absorb the research and resource development activities of the Bureau of Mines, leaving the regulatory and enforcement functions related to mine health and safety in a separate organizational setting. This accords well with the recently announced reorganization of the Bureau of Mines which has separated its health and safety enforcement functions from its minerals research, resources, and environmental development functions.[38] Utilization of the research and resource development capabilities of the

Bureau of Mines would give NIMRAD a ready made technological base for its activities. Additionally, the minerals exploration research function of the Geological Survey might also be added.

5. Management and Direction. The executive director of NIMRAD should be a presidential appointee, with the advise and consent of the Senate, at least at Executive Level V. Staff assistance to the executive director should be provided by career staff experts in appropriate areas of the physical sciences, engineering, and the social sciences.

6. Participation and Representation. A board of directors should be established to advise the NIMRAD executive director. This board should be composed of representatives from Congress, federal agencies, state governments, universities, industry, labor, and the general public as represented by conservation and environmental protection interest groups. The board members should be appointed by the President or by the Secretary of the Interior, and they should meet regularly and periodically. The board should designate standing committees based either on functional areas of technology or on commodities. Membership in each committee should include a broad representation of subject matter specialists and knowledgeable laymen. The committees will function in a recommending capacity to the board on matters of minerals policy, project allotment, institutional development, and monitoring and evaluation of research.

7. Functions. The principal functions of NIMRAD should include continuing appraisal of resource supply/demand conditions; determination of areas of research emphasis; award of research projects to competing

institutions; encouragement of pooling of resources by government, industry, and universities; oversight of intra-mural research operations; and development of stronger minerals education institutions.

8. Operation. Through planning and policy evaluation, NIMRAD should determine technological objectives. These objectives should be translated into action programs through the recommendations of the functional or commodity committees. The committees will evaluate and recommend research projects to the board. Project allocations should be on the basis of competition between intra- and extra-mural research facilities. Work will be evaluated periodically for its contribution to the accomplishment of program objectives.

9. Physical Facilities. In the first stages of implementation, no major physical facilities will be required. The executive director and the board of directors, with its attendant committees, should be based in office and meeting space in Washington, D. C. As the organization of NIMRAD develops, the physical location of its direction and management functions should be in conjunction with a substantial intra-mural research facility. The required relocation of the Bureau of Mines research center presently located at the University of Maryland will provide a logical opportunity for establishment of a new facility for NIMRAD. This facility can provide research equipment and opportunity for researchers from a wide variety of participation institutions and also training opportunities for graduate students.

E. PROSPECTS FOR IMPLEMENTATION

As previously noted, many suggestions have been made in the past hundred years for establishment of governmental institutions for minerals technology. Some institutions have been established, but only in a fragmented and particularistic fashion. One may well question why no suggestion for a unified and coordinated approach to minerals problems has yet been implemented. One may also question the implications of past neglect for the recommendation contained in these pages.

At the outset, policy is not made and institutions are not created in a vacuum. They respond to social needs made manifest through the political and economic process. In the minerals sector, the political and economic process has not brought forward the kind of institution that seems from an objective and rational standpoint to be essential for continued national growth and material strength. Many reasons for this may be suggested.

First, there is the fragmented nature of the industry itself and its relatively low level of technological intensity. Second, there is the separateness that exists between the primary governmental minerals agency — the U. S. Bureau of Mines — and the minerals industry. As Norton Long pointed out years ago, governmental agencies in the American system must develop constituency relationships and must serve as channels of representation for the constituents in order to carry out agency responsibilities.[39] Third, there is a separateness between the Interior Department and the Congress which was revealed by the Department's refusal for ten years to support Senator Allott's call for a national minerals policy. Only in 1969 did the Department take a favorable position on Senator Allott's proposed legislation.

Other possible reasons include the decline of the minerals educational establishment. Little initiative in any concerted sense comes today from the universities where minerals studies are in a state of advancing entropy. Finally, there is no sense of dramatic emergency about minerals problems. There is no "minerals Sputnik" to jar the national consciousness. A change from a decreasing to an increasing cost curve for minerals is insidious, not dramatic. This is coupled with the public "gold rush" mentality, alluded to earlier, which optimistically assumes that the riches of the earth only need to be discovered in the romantic ways of the forty-niners in California and "The Unsinkable Molly Brown" in Colorado in the nineteenth century.

Given these kinds of conditions and attitudes, the prospects for the establishment of a National Institute of Minerals Research and Development become somewhat remote. And yet, a beginning exists with Senator Allott's proposed legislation to establish a mining and minerals policy. This bill (S. 719) offers a vehicle to which could be attached an institutional mechanism such as NIMRAD. If this were done, the combination of policy and institution would then serve as a rallying point or at least as an arena within which industry, the educational establishment, state governments, and the public could come together with the executive and legislative branches of government to begin working out solutions to national minerals and materials problems.

The existing situation in the minerals sector is not really a vacuum. The constituent elements are merely too remote from each other. We are suggesting that the combination of national policy and institutional mechanism will serve to pull the elements closer together and speed up their reactions to each other in a kind of organizational Boyle's Law. There is nothing radical in this proposal. The concepts and mechanisms exist in other governmental program areas. But the initiative in the minerals sector must come from government, and in this case from a joint enterprise of the executive and legislative branches. An act of initiative here, with modest funding, will serve as a starting point for pulling together the pieces of the minerals sector.

F. CONCLUSION.

The overriding purpose of the proposed National Institute of Minerals Research and Development is to establish an institution which will be in reality what George Kolstad has described in theory for the AEC as "an adventure in the purpose and performance of a free people building private and public institutions, large and small, and in the interaction of these people in their personal relationships, their community, their state, their region and their country."[40] Successful implementation of the adventure will mean full utilization of all sectors of the nation in meeting increasing challenges of mineral supply and utilization. It will mean establishment of national policy, careful governmental planning of technological programs, mutual effort of all sectors in accomplishing objectives, and contributions and participation from the broad public constituency.

The proposed National Institute of Minerals Research and Development can serve as a focal point for translating national minerals policy into effective programs. This can be done through the recognition and

and encouragement of interrelationships between governmental, academic, and industrial enterprises. Additionally, the Institute can serve as a forum for greater participation in a vital area of national policy by conservation organizations and by representatives of other lay citizen groups. The need is apparent. An institutional mechanism is necessary. If establishment of the Institute properly takes into account considerations of the scientific establishment, the governmental structure, funding, political support, industrial development, public participation and representation, and effective internal organization, then the national interest will be well served.

FOOTNOTES for CHAPTER VI

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