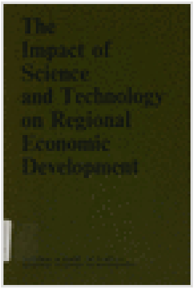

Impact of Science and Technology on Regional Economic Development; an Assessment of National Policies Regarding Research and Development in the Context of Regional Economic Development (1969)

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The Impact of Science and Technology on Regional Economic Development

An assessment of national policies regarding research and development in the context of regional economic development

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Dr. Frederick Seitz, *President*
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The Committee which you have appointed to make a study of science, technology, and regional economic development submits the attached report which summarizes its work.

The members of the Committee have heard many presentations, and have read reports from many individuals and organizations, including carefully prepared testimony before Congressional hearings. As indicated by their affiliations and titles, the members of this Committee hold professional positions in industry, in government, in educational institutions, and in other non-profit institutions; a number have had substantial experience in two or more categories of institutions. The findings and recommendations presented here represent the opinions and insights of this Committee arrived at and assembled after many conferences and discussions. The content of the report is viewed not as a research report but as a presentation of the combined judgment and the general agreement reached by the Committee. It does not necessarily represent individual endorsement of the details of each recommendation.

It is important to recognize that the findings and recommendations herein presented have emerged from the adoption of certain perspectives which are based in part on the original charge to the Committee and in part on the insights which have been gained in the course of the study. The initiating "Scope of Work" statement requested the Committee "to conduct a study of the impact of science and engineering on regional development, and of the effect of Federal scientific and technical policies [on regional development]. . . ." The Committee immediately recognized that many activities *other* than research and development have an important impact on the economy of various regions. Furthermore, there are policies at both the Federal and state level which affect regional economy but are not addressed specifically to R&D. We have been repeatedly reminded that in many instances, the economy of a depressed region might be more immediately strengthened by the establishment of a new labor-intensive industry with little or no R&D component than by a high-technology installation. Thus, the emphasis of this report on the potential contributions of R&D to regional economy is attributable to the charge to the Committee and not to the parochial view that research and development constitute the only avenues to solutions of regional problems. Similarly, the rationale for the emphasis on the role of the Federal government originates in the work statement posed by the Department of Commerce. Although this report is concerned largely with Federal policies or programs, we have concluded that many of the solutions to regional problems are to be sought in the encouragement of entrepreneurial activities in the private as well as the public sectors and at local, state, and regional levels.

Following is a brief listing of some of the highlights of our report:

1. In the consideration of national policies for R&D, it is important to distinguish between two major categories of national goals for R&D, in the context of which further recommendations are made:

   Central National Goals for R&D—such as leadership in the important fields of science, nuclear power, space exploration, and national defense—in which the program is national in focus, sponsorship, funding, and overall direction.

   Distributed National Goals for R&D—such as the development of human resources, the rebuilding of our cities, water resources, and regional environment for living—in which the programs are characterized by local determinants in the nature of the problems, in the approach to solutions, and in their anticipated consequences.

   These goals, while related in many areas, require distinctly different criteria for establishing priorities and means for implementation.

2. In attempts to develop or to initiate new programs, plans, or approaches to the solution of regional problems, it does not suffice to generate a carefully considered plan or to solicit the advice of a qualified group of experts. While competent, technologically sophisticated organizations or individuals are required to provide analyses and designs for the future, it is essential to elicit a knowledgeable client-sponsor capable of implementing such plans. In most cases, the client-sponsor must be clearly identified at the planning stage in order to stipulate the various social, political, and technological constraints within which solutions may plausibly be set forth. It is our considered view that the establishment of a client-sponsor is an essential step in the design of a program to solve regional or local problems. Such a client-sponsor might be a Federal or state agency, or a compact between such agencies; but it might include or be constituted by

a group of private individuals or a combination of public and private corporations. One aspect of our changing national environment is that so many economic and social problems extend beyond the political and geographic boundaries of the municipalities and states in which they are located. Repeatedly, it has been necessary to designate or to establish a client-sponsor to act on behalf of the larger community or region in dealing with such problems.

3. A key requirement in the attainment of social and economic objectives for a given region lies in the development of human capabilities and talents, and the attraction or retention of the most gifted and innovative segment of the population. To provide for the maximum development of human resources, access to quality institutions of education should be available to citizens in all regions of the country. Since graduate research helps to provide superior educational opportunities at the university level as well as innovation at all levels of education, there should be a national commitment to the development and further improvement of centers of scientific and academic excellence in all major regions, particularly in those now deficient in such facilities. Our recommendations reflect a continuing commitment to the project form of support for graduate research in universities; in addition, we have recognized the need for an enlarged program of institutional and block grants. The latter programs are needed to strengthen graduate research institutions in all regions of the nation, as well as to support applied academic research on problems of a regional or distributed nature. The Committee has also recognized the need for innovation in our educational institutions, both in their orientation to a wide set of educational objectives and in new approaches to educational facilities and processes. Institutional grants for modern computer and library facilities should be made widely available so as to provide access to knowledge for students at colleges and universities in all parts of the nation.

4. R&D programs aimed at distributed national goals should be carried out in two categories of R&D institutions—one oriented toward problems which many regions share in common, the other directed to the problems of a given region. The Committee found a need for a new type of R&D institution, whose principal institutional mission would be to encourage the technological and economic development of the region in which it is located. As a pilot experiment, a small number of such institutions, referred to as Exploratory Centers for Regional Development, should be established in regions in which needs exist and which are reasonably delineated in terms of geographic and political compatibility. In view of

the increasingly urban, mobile, industrial, and service-oriented society which such Exploratory Centers would be called upon to serve, they would have to be broad-based institutions equipped to deal with complex systems problems and to carry out entrepreneurial functions. The Committee found it easier to describe the functions of such Centers than to specify their organizational structure. The functions, which are described in Chapter VI, include (1) a continuing survey of regional problems and resources, (2) social and technological invention—the matching of potential solutions to possible needs, and (3) innovation and public service—the transfer of new ideas, commercial products, organizational processes, and ways of doing things into widespread use in the region. A key role would be the identification of public and private client-sponsors to implement new ventures aimed at the improvement of the economy and way of life in the region.

5. We have noted throughout the report a special need for entrepreneurs and the entrepreneurial spirit—a need to relate and involve the private sector in programs set forth in the public interest. The role of the individual entrepreneur—whether engaged in industrial, technological, financial, or civic affairs—is a key factor in developing new opportunities and in solving the problems of depressed or underprivileged segments of our society. It remains a continuing challenge for leaders in private industry as well as in government or in the various categories of R&D institutions to evolve an increased and mutually supportive relationship between the public and the private sector to address social and economic problems.

We submit our findings and recommendations with a full recognition of the need for further studies and for the adoption of new perspectives in the approach to the regional problems of our times.

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Preface

Twentieth century man will not be remembered for inventing the atomic bomb but for daring to think he can use science to achieve the good life.
—Arnold Toynbee

To assist in its work, the Office of Regional Economic Development of the Department of Commerce has requested the National Academy of Sciences and the National Academy of Engineering to undertake a study of the impact of science and technology on regional economic development, to assess "the effects of Federal scientific and technical policies upon regional development, and to make appropriate recommendations of actions or changes in policies. . . ."

This study was initiated with a series of conferences sponsored by the National Academy of Sciences early in 1967. In November of that year, the members of this Committee, most of whom had taken part in the earlier conferences, were asked to carry out the formal task of formulating an assessment and issuing this report.

The Committee wishes to express its sincere appreciation to the many individuals who have made important contributions to this report in the form of presentations, contributed papers, and constructive criticisms on the various aspects of this work. These include participants in the conferences on regional economic development (as listed in Appendix C) and members of the Committee on Science and Public Policy of the National Academy of Sciences.

The Chairman wishes to acknowledge the cooperative spirit and the many individual contributions of the members of the Committee who have given profusely of their time, have helped in the several revisions of the report, and have worked together to develop new insights and perspectives.

The Chairman also wishes to acknowledge the contributions of the staff and, in particular, the effective and conscientious editorial assembly of this report by Mrs. Peggy Harris and Mrs. Donna Avolt of the Graduate College of the University of Illinois.

Daniel Alpert, *Chairman*
Committee on Science,
Technology, and Regional
Economic Development

Urbana, Illinois
January, 1969

Contents

Introduction

The Changing Perspectives of This Study

The perspectives adopted by this Committee have been characterized by change. On the one hand, there have been changes in the over-all external environment in the course of the study, changes in the ordering of federal administrative and congressional priorities and concerns with regional issues, and changes in the public attitudes toward the role of the federal government or of private industry in dealing with state or regional problems. Furthermore, the insights and understanding of the Committee have changed in the course of time. The topics that generated much discussion in the early stages of the study have given way to others, due partly to growing insight as to the priorities to be assigned, and partly to changes in the national setting.

The environment in which this study was initiated is typified by the congressional hearings carried out in 1966 and 1967 by such committees as the Subcommittee on Government Research of the Committee on Government Operations (United States Senate), Fred R. Harris, Chairman; the Subcommittee on Science, Research, and Development of the Committee on Science and Astronautics (United States House of Representatives), Emilio Q. Daddario, Chairman; and the Subcommittee on Employment, Manpower, and Poverty of the Committee on Labor and Public Welfare (United States Senate), Joseph S. Clark, Chairman. The proceedings of the hearings of the Harris Subcommittee are entitled "Equitable Distribution of R&D Funds by Government Agencies,"[1] a title suggestive of the political and economic issues encompassed. They provide striking evidence of the great expectations that society has generally associated with science and technology and of the increasing sophistication with which Congress is searching for answers in its decision-making roles.

What are the public expectations concerning the impact of R&D on the economy? These are varied and seem to depend greatly on the context in which the question is posed. There would seem to be consensus as to the relationship between a powerful R&D program and a growing national economy. However, when the impact of R&D on specific regional development is at issue, there are considerable differences of opinion. The statements of public figures representing individual states or districts often show great optimism as to the economic impact of a given R&D installation or contract. Typical of this viewpoint is the following statement of the Senate Subcommittee on Employment, Manpower, and Poverty:

> Research and development funds in conjunction with trained manpower have both direct and indirect economic effects, which often act as a significant spur to growth and development. Industry and education play major roles in the growth process, and thus the research and development funds awarded to business and schools in a particular area are of vital concern to the inhabitants of that area. *Despite the difficulty of making precise measurements, the connection between research and development funds and regional development—or stagnation—is both clear and obvious.* (Emphasis added.)
>
> Consider, however, the effects upon the area that receives little or nothing in the form of research and development awards from the Government. Scientific and technical talent is less attracted; the best scientists its universities produce are more likely to leave. Its industry tends to become obsolete; new industry is rarely drawn. Its schools are more likely to be inadequate; better schools are less likely to be constructed. Its inhabitants are less likely to prosper, for if a critical mass produces an industrial and educational oasis, its absence may well produce a wasteland.[2]

Whether such strong expectations are borne out by the evidence to date is seriously open to question. The more conservative views of expert observers are typified by the statement of Mr. John G. Welles of the Denver Research Institute:

> Any region, whether composed of a few counties or a number of states, is vastly more complicated and difficult to understand than the most sophisticated space or weapons system. We humans know how to develop the specifications, to produce, and to operate the latter, but not the former. A region may be viewed as a varied and intricate combination of interacting systems—social, economic, political, psychological, and technological. We simply do not know very well how to predict what will happen within the region in response to actions of the Federal government.[3]

In view of such wide differences in expectation of benefits to the regional economy derivable from the expenditure of R&D funds, it is one of the central purposes of this report to delineate the relationships between R&D and regional economic development.

It should be expressly noted that the Committee recognized from the outset that many activities other than research and development may have an impact on the economy of various regions, and furthermore, that many national policies at both the federal and the state level affect regional economies though not specifically addressed to R&D. The emphasis of this report on the implications of R&D for the economy of various regions originates with the specific charge to this Committee and not with the parochial view that R&D constitutes a panacea for all problems. Similarly, the emphasis in this report on the role of the federal government is also attributable to the nature of the task assumed by the National Academy of Sciences and the National Academy of Engineering. Although this report is addressed largely to the implications of federal policies concerning R&D, we have recognized from the outset that the key to the solutions of many regional problems lies in the encouragement of local initiative at the state and regional levels, and of entrepreneurial and innovative activities in both the private sector and the public sector.

It should have been expected that although addressed to the special policy issues related to R&D, this study would inevitably be confronted with the broader questions regarding national policies and objectives for regional economic development. In the course of our work, it soon became apparent that while certain broadly stated premises might be generally accepted, there does not as yet exist a well-established conceptual framework within which to consider or, in operational terms, to specify many regional problems. Neither is there as yet a clearly established policy for regional planning on a national scale. Although there is obviously an increasing national interest in these issues, the "definitive book" on this subject has not as yet been written.

For these reasons, the Committee has sought to establish a framework within which national policy for R&D in support of regional development may be considered in the future. Thus, many of the findings and recommendations of this report are set forth in terms of broad objectives rather than in terms of specific program recommendations.

Since the process of establishing broad perspectives is difficult and time-consuming this report does not address all the issues that the Committee has encountered. A number of issues, though recognized as important and relevant, have been referred to in passing, but were not sufficiently resolved in the course of our deliberations to justify specific recommendations. Examples of such issues are the mechanisms within the federal government for relating or evaluating the R&D efforts of various agencies in support of given regions, the needs for resource planning at the national level, and the "brain drain" problem stated in regional terms.

Finally, it should be noted that the Committee views this report as a part of a continuing process of study and restudy. Broadly stated, the issues we have addressed involve the concern for the sponsorship and management of science and technology in the general public interest. For the most part, the support of R&D has been sought and justified in terms of the principal mission for which it was initially sponsored—e.g., national defense, industrial efficiency, or agricultural productivity. Yet, in virtually all cases, an expanding technology has brought about secondary or long-term consequences for society, which, though seldom anticipated, were even more profound. To examine present federal policies for R&D in the context of the social or economic welfare of a community or region is to enter into a new and difficult domain—particularly since the program objectives for most of the presently sponsored R&D are aimed at other primary missions, whereas the impact on a given region, however significant, is often an unintended by-product.

In submitting this report, we are conscious of how many questions we have addressed and how few we have resolved. In no small measure, this circumstance is inherent in the broad terms of our task statement: in a sense, we have been asked how science and technology may be used in the common interest without having specified what is in the common interest. To address issues of this broad character calls for qualifications to which no one discipline or field of expertise can lay special claim; if this Committee may set forth a claim to be heard, it lies in the diversity of the educational background, institutional affiliation, and professional experience represented by its membership. The insights which we have gained from this attempt make us more aware of the need for further study, particularly to consider some of the recommendations of this report in more quantitative terms. We are persuaded that the issues raised deserve such study.

Some Basic Premises

A first premise underlying this report is the widely held view that the economic well-being of our nation is dependent on the development of its technological potential. For example, the 1964 Annual Report of the Council of Economic Advisers noted that ". . . the crucial element in the rise of our national well-being has been the progressive utilization of our ever-growing store of knowledge of the world in which we live."[4]

That the role of science and technology is considered to be of great significance to the social and economic welfare of the nation is manifested by the number of studies that have been initiated and carried out in recent years. In February 1966, the National Commission on Technology, Automation, and Economic Progress, appointed by the President, issued its report, *Technology and the American Economy.* This report, which represents a significant step forward in the common understanding of the role of science and technology in our society set forth the following observations:

There has been widespread public recognition of the deep influence of technology upon our way of life. Everywhere there is speculation about the future possibilities for human life, and much public attention is directed toward scientific and technical trends. The vast majority of people quite rightly have accepted technological change as beneficial. They realize that it has led to better working conditions by eliminating many, perhaps most, dirty, menial and servile jobs; that it has made possible the shortening of working hours and the increase in leisure; that it has provided a growing abundance of goods and a continuous flow of improved and new products; that it has provided new interests and new experiences for people and thus added to the zest for life.

On the other hand, technological progress has at various times in history, one of them in recent years, raised fears and concerns which have led to some questioning of its benefits. . . .

When the impact of economic and technological change has caused certain regions to fall behind the progress of the nation as a whole, the Federal government has found itself with new responsibilities. . . .[5]

The last sentence in the above quotation summarizes a *second major premise: namely, that federal policies must be established on the basis of a concern not only for the well-being of the nation as a whole but also for the well-being of the various regions within it.* Indeed, the purpose of the Public Works and Economic Development Act of 1965 was:

to provide new industry and permanent jobs in areas where they are most needed. Its main emphasis is on long-range economic development and programming for areas or communities that are burdened with persistent unemployment and low family incomes. . . .

The new act has a single primary objective: to create a climate conducive to the development of private enterprise in America's economically distressed communities. . . .[6]

The Act is a prime example of concern in our representative democracy with the economic welfare of its individual regions as well as that of the nation as a whole. Not only is a depressed region a negative element in the economic well-being of the nation as a whole, and hence of national import, but the individual congressional representative from such a region has specific responsibilities for the social and economic well-being of his constituency. Major federal policy decisions and programs can not in the long run avoid the careful scrutiny of the legislators from all states of the Union in terms of the implications for the people of their own regions, nor can major new programs be established without broad support.

That national policies with respect to science and technology have become a matter of political as well as economic interest is testified to by the increasing attention given to science policy by Congress in recent years. Indeed, during the past year, the Subcommittee on Government Research of the Senate Committee on Government Operations found it useful to publish "An Inventory of Congressional Concern with Research and Development."[7] This interest in and preoccupation with science policy stems from the growing public awareness of the great leverage provided by modern science and technology in opening new areas for industrial, educational, and governmental development. In addition, the total federal expenditures for research and development have grown to increasingly significant proportions of annual congressional appropriations. The total national expenditures for R&D rose from approximately $140 million (or 0.15 percent of the Gross National Product) in 1930 to over $20 billion (approximately 3 percent of the GNP) in 1965, while the federal contribution rose in this period from about $23 million to almost $15 billion. On the basis of such financial commitments, quite apart from the multiplying factors that R&D is presumed to have, science policy is likely to occupy the keen attention of our major decision-makers in the foreseeable future.

A third major premise in this study is that the relationships between science, technology, and a national or regional economy are complex and must not be described or assessed in terms of one-to-one relations or direct causal connections without reference to external factors. To begin with, the political interest in this element of the national budget is not based solely on the short-range economic implications of federal expenditures, but on the much greater long-range implications that R&D is presumed to have. Indeed, the direct employment and income created by R&D is quite small even in California, the recipient of more dollars for R&D than any other state (approximately 6 percent of the total personal income). Rather, the expenditure on R&D is typically viewed as an investment; most researchers estimate that money spent on research has its greatest impact on the economy long after it is spent, as the subsequent benefits from this investment are adopted into the framework of society.

Despite the disproportionate attention given to this segment of the national effort, its role in the national economy is not easy to appraise or to quantify. The relationships of R&D to national or regional economic welfare are so complex that resorting to statistical data may lead to oversimplified and invalid conclusions. This is so because there is not a simple causal relationship between the R&D activities or the institutions in which they are carried out and the subsequent effects on the economy. Dollars spent on R&D in a corporation's central research laboratory in New Jersey may have little effect on the economy of that state; rather, it may have a far greater impact on the economy of Georgia, where a manufacturing division of that corporation is located. Funds spent on R&D in one industry, e.g., the computer data-processing industry, may have a revolutionary impact on another industry, e.g., banking or insurance. In some cases (e.g., solid-state electronic devices), technologies developed with federal funds for military purposes have had far greater impact on civilian industries than comparable amounts of funds spent by the same industries on the development of their own civilian products. In such a complex interplay as to where or when new technologies may have an economic or social impact, it is essential that an assessment of policy decisions take into account the nature of the research and development functions and the manner in which the results of such efforts are incorporated into the economy. Harvey Brooks has indicated the complex interplay between science and technology in the context of regional or national economies:

Although a decade ago there was a simplistic notion of the relation between science and economic development, it is now generally realized that, while the two are connected in a general but important way, they are not particularly closely coupled—industry by industry, region by region, or even country by country. Thus, while there is little question that general industrial advance in all the developed nations depends on the continuing advance of science, it is also true that the diffusion of knowledge in *fundamental* science throughout the world is so rapid that the local advance of industry depends more on its coupling to science and to markets than it does on the particular location of scientific activity. Thus, for example, the United Kingdom, which has the highest per capita production of Nobel Prize winners, and produces the highest proportion of fundamental scientific papers in relation to population, has been notoriously lagging in economic growth. By contrast, the two most rapidly growing industrial nations, Italy and Japan, are among the largest importers of foreign technology.[8]

It is a fourth major premise of this study that the long-range general physical and social welfare of man are of overriding importance in the development of policies for the utilization of science and technology. The technological revolution in agriculture, which has made American agriculture the universal model for achievement and hope in feeding the world's population, brought in its wake regional problems in the southern states that have been distributed though not alleviated by transferring the burdens of an underprivileged, poverty-stricken portion of the society to all the major urban centers of the nation. Technological advances have tended to place the "have" regions of the nation and of the world in positions of greater relative advantage over the "have-not" regions. And even in the affluent regions of our country, the introduction of technology has often been accompanied by many deleterious consequences for individuals or for society that were not previously considered or taken into account.

In the words of Charles Frankel:

Technology, plainly, is the fundamental dynamic element in modern society. It affects everything from the size, shape, look, and smell of our cities and suburbs to the mobility of populations, the character of social classes, the stability of the family, the standards of workmanship that prevail, and the direction and level of moral and aesthetic sensibilities. The decision as to when, where, and how to introduce a technological change is a social decision, affecting an extraordinary variety of values. And yet these decisions are made in something very close to a social vacuum. Technological innovations are regularly introduced for the sake of technological convenience, and without established mechanisms for appraising or controlling or even cushioning their consequences.[9]

The great challenge to our society is whether technology, which has helped make our country the symbol of affluence to the other nations of the world, can be used to solve the problems it has helped to create.

The Implications of R&D Activities and of R&D Location for Regional Economic Development

Much of the ambiguity in the discussions of R&D vis-à-vis regional economic development has resulted from the fact that underlying the discussions there are two distinctly separate though related assumptions regarding the potential contributions of R&D.

First, there is the assumption that many of the economic or social problems of various regions of the country are amenable to solution through the use of the techniques of modern science and technology. Analogy is often made between the solution of the problems of a region such as Appalachia and the problems of space travel. In this case, what is involved is research and development as an *activity*, and the contribution that the R&D activity can make to the solution of the stated problems, but independent of the location of the laboratory or facility in which it is carried out.

Second, there is the assumption that the deployment of R&D *facilities* in a given region has a positive economic effect on the local environment, independent of the objectives toward which the R&D activities are directed and whether funded by local or outside sources. The facilities in question may be industrial laboratories, governmental laboratories, not-for-profit research institutes, or universities. Since the R&D activities in each of these facility categories receive financial support in major proportion from federal agencies, the distribution of federal support is viewed as a mechanism by which regional development may be strongly affected.

Some of the confusion and concern in this discourse might be alleviated if it were recognized that both of the above assumptions may be valid in many instances (indeed, we believe them to be so); to fail to distinguish between them, however, may lead to serious confusion in the discussion and formulation of policy. One can find profuse examples not only of communities that received economic benefits from locally situated R&D institutions but also of communities that received comparable economic benefits from R&D activities carried on elsewhere. If R&D activities are considered outside the context of the institutional relationships in which they are carried out, it is highly unlikely that such considerations will lead to valid policy recommendations. It has been one of the objectives of this study to examine R&D and economic development in the framework of the variety of mechanisms by which they may relate to each other.

Chapter I

Major Objectives of Federal Policies for Research, Development, and Regional Economic Growth

The affluent economy we enjoy in the United States today has in large measure been made possible by the application of scientific knowledge and technology. This has remade the way people live and work. The application of the fruits of scientific research and technological innovation has given us the capacity to release men—not the elite few, but the broad masses of men—from the relentless pursuit of subsistence. Soon two thirds of our work force will be engaged not in producing goods, or food, or fiber, but in providing *services* in such fields as education, health, finance, government, sales, and recreation. Yet, while the application of science and technology has made this transformation possible, large areas of our country and a substantial segment of our population have been unable to share adequately the fruits of this new society. Variously labeled "the invisible America" or the "unseen poor," they are neither invisible nor unseen any longer.

The costs of social change resulting from technological progress are often borne by those elements of society and regions of the country least able to sustain them. We have not developed the political, social, or economic mechanisms for distributing the costs or benefits of technological progress sufficiently equitably so that its net desirability can become more obvious to all. The nation should commit itself to the task of assuring that citizens in all regions of the country may benefit from the fruits of scientific knowledge and advanced technology, particularly with regard to the fuller development or accessibility of under-utilized resources.

It is the opinion of this Committee that social, economic, and political policies and institutions can be created that will provide for more effective utilization of scientific knowledge and technology throughout the country among all segments of the population. As a first step toward developing such policies, present national scientific and technical programs and policies should be assessed in order to determine how or whether they can contribute to regional as well as national growth.

Major Objectives of Federal Programs in R&D

In congressional testimony, Dr. Donald F. Hornig, then Science Adviser to the President, specified the principal federal goals in supporting science in academic institutions:

I assume we can agree that we are pursuing several interrelated goals in our federal support of science in the universities.

We wish to ensure that our nation either leads or is at the forefront of research in the most important fields of science;

We would like to make available to all young people, wherever they live and whatever their economic level, the possibility of education of the highest quality;

We wish to develop strong intellectual centers in all parts of our country that can provide the focus and the manpower for modern technological development.

In the period since World War II, the first goal has been the major concern of most agencies supplying federal support. . . . Our efforts have been successful; we are now a world leader in scientific research.[12]

Dr. Hornig's testimony indicates that there are a variety of goals for science and research; similarly, there are a number of goals for technology and development.

This Committee has found it valuable to classify federal programs for R&D into two broad categories, in accordance with a suggestion by Dr. J. H. Hollomon.[13] First are high-priority programs, widely considered to be vital to the welfare of the nation as a whole, and directed toward what we designate as "central national goals." These programs have one characteristic in common: they are programs with a national focus; in most cases, the client or patron is the American public as a whole, rather than any specific locality or region of the nation. There are not marked differences among regions either in the commitment to such programs or in the anticipated major consequences. Examples include national defense, space exploration, high-energy physics, nuclear power, a cure for cancer, and national eminence in science. Generally speaking, they are programs for which there is a national commitment to achieve identifiable goals.

Typically, programs aimed at central national goals are in large measure initiated and sponsored by mission-oriented federal agencies, often through grants to and contracts with organizations of demonstrated competence. In addition to these primary objectives, the agencies carrying out such mission-oriented programs have a secondary responsibility to the nation: to assure that there will be adequate scientific and technical resources, both human and material, in their fields of interest in the years to come. This longer-range goal, however, does not have the priority that attaches to the primary mission, whether it is to solve the mysteries of cancer, to defend the nation against external enemies, or to unravel the secrets of the atomic nucleus.

The Committee has proposed that the second category of goals for federal R&D programs be designated as "distributed national goals" in R&D. The concern may be national, but the problem, its solution, and the consequences thereof are decentralized. Included in this second category are R&D efforts aimed at improvements in agriculture, in water resources, and in the physical environment; other examples are R&D directed toward regional economic development or the rebuilding of cities. Although these programs represent a broad national commitment, they share in common a strong local ingredient; i.e., they are characterized by the need to specify in regional terms both the nature of the problems to be solved and the nature of the approach to the solution. Dr. Hollomon describes this group of programs as follows:

> Instead of highly centralized direction and management, this category of federal support reflects a pluralistic, decentralized approach, both geographically and institutionally.
>
> Government, at all levels, as well as private industry and nonprofit organizations are involved in the decision-making process and funding leading to research for the solution of these problems. Geographically, for example, the agricultural technology useful in Wisconsin is quite different from the agricultural technology appropriate for Arizona. Yet both areas need technological competence per se.[13]

This Committee believes that there is a need for a more adequate national commitment to promote the economic well-being of the various regions of the country and, as a necessary ingredient, a need for national programs that provide for technological competence in these regions.

Our free-enterprise system has built-in features that place demands on a given industrial enterprise to be receptive to the incorporation of new technology in order to survive in a competitive environment. Similarly, the economic and military strength of a nation relative to others is generally recognized to depend on the development of technological capability and innovation.

Note the present concern in many European countries over U. S. technological superiority.

Although the vitality of a metropolitan community or a backward region of the country may also depend in a similarly critical way on the proper incorporation of technological advances, there are no indicators such as corporate profit or balance of payments to specify that need or its magnitude. Nor is there typically a governing body to assure the economic viability of a region as a unit. Although some states have made significant efforts in behalf of their own economic development, the natural framework for economic and social development frequently does not conform to state lines. Hence, the incorporation of R&D or the development of long-range plans has not been systematically employed at local or regional levels.

To aid in the development of regional competence, action by the federal government may be necessary, but not sufficient. Local efforts and local organization are absolutely indispensable to success in meeting regional goals.

However, this Committee believes that the states and regions of the country can not acquire and retain the scientific technological resources to sustain and improve their economies unless there is a more adequate public recognition of the need for a distribution of competence itself throughout the country and a public decision to do something about it. *There is need for an enlarged and clearly defined program of distributed national goals in R&D.*

The Committee furthermore believes, however, that we can not and should not "remedy" regional technical disparities by imposing on programs whose primary concerns are our *central national goals* some arbitrary distribution formula for R&D funds based solely on population or geography. To do so would be to ask that these vital national programs be carried out under criteria that would permit inefficient use of the resources applied to their urgent objectives. Nor do we have evidence that there would be a major contribution to economic vitality in regions not otherwise adapted to support or benefit from such efforts.

As is the case for programs aimed at central national goals, support of programs concerned primarily with distributed national goals must be established on a *selective* basis. The criteria and mechanisms for implementation of distributed national programs may differ, but the development of scientific understanding and the encouragement of technological innovation can be successful only if practicable means are found to provide selectivity in the support of R&D.

Assessment of the funding required to maintain adequate programs in these two major categories of R&D must entail a careful and detailed analysis of the separate objectives of each category. Although the technological competence in underdeveloped regions might be enhanced by a buildup of programs in either category, it does not follow that a uniform distribution of R&D support in both categories would meet either national or regional needs. Furthermore, while certain regions have attained sophisticated technological competence through implementation of central national programs in R&D, it would be a serious over-simplification to assume that all their regional problems were thereby solved.

Federal support is needed to implement programs aimed toward a wide variety of central and distributed R&D objectives. The need for support of central national goals has been recognized by the nation at large, and, in general, suitable mechanisms have been devised to implement them. However, the potential returns to society from programs aimed at distributed national goals in R&D have not yet been generally appreciated; nor have adequate means for their implementation been widely adopted. There is reason to believe that present levels of funding are inadequate to serve both major categories of national goals. It is within the context of these observations that the further findings and recommendations in this report are set forth.

Objectives of Federal Programs for Regional Development

In broad terms, national policies for regional development should have two primary objectives:

To improve incomes and levels of living in regions by making it possible for the people in each region to increase their contributions to the national economy through development of the region's comparative advantages and fuller utilization of its manpower and other resources.

To assist in correcting major imbalances in the availability of social and economic opportunities among some parts of the nation and between some regions and the country as a whole.

However, each region of the country can not possibly become a duplicate in microcosm of the national economy. Inter- and intra-regional migration will continue as individuals and institutions seek new opportunities; diversity, migration, and change are all elements of growth and development.

Obviously, a seaboard region has different opportunities for development from those of a region deep in the interior. A sparsely populated, arid region calls for regional development objectives different from those required in a more densely populated, humid one. Regions isolated from the main economic heart of the country in less-desirable climatic areas call for a different approach than those similarly isolated in more attractive climatic zones. The level of development each region can attain without imposing excessive costs on the country as a whole depends upon many factors. It is true that national affluence, science, and technology make it possible, if we wish, to create major new population centers and economic complexes where we choose, even under the most adverse conditions. But there is sometimes a profound difference between what is technically possible and what is in the best national interest. An attempt to develop, without understanding all its implications, a homogeneous distribution of population and economic activity across the country would impose upon the nation excessive costs of production supported in the form of public subsidy. These costs would eventually be felt by every consumer and taxpayer, as well as in the ability of American products to compete in world markets.

This Committee believes that the objective of "balanced development" as set forth in the Economic Development and Public Works Act of 1965 can never be attained if it is construed to mean a homogeneous distribution of economic activities among the regions of the country.

The Committee does believe, however, that if somewhat differently defined, the objective of balanced regional development can be met.

Cities and regions inevitably specialize in products and services that they export to the rest of the country. Incomes and growth are a function of that regional specialization, and high incomes are normally associated with a favorable mix of high-growth activities in those sectors for which the region can offer particular comparative advantages.

Unfortunately, and not unexpectedly, the underdeveloped regions of the country tend to specialize in slow-growth and/or declining sectors of employment such as mining, fisheries, agriculture, and the declining or static sectors of manufacturing. Some regions experience slow growth because they have been bypassed by a developing economy or have found themselves saddled with slow-growing industries. Others, in an attempt to develop a more substantial economic base, have sought to attract new industry into their regions and have found it easiest to attract the kind of industries that are slow-growing and technologically underdeveloped. Frequently these industries are attracted by low wages and can meet their requirements with an unskilled and undereducated labor force. Regions with such industries presently lack many of the institutions, public and private, required to help them correct this imbalance. In such cases, the objective of balanced growth should be viewed as the attempt to develop a regional economy in which the sectors of growing employment outweigh the declining sectors—an economy ultimately capable of sustaining sufficient growth to maintain a high rate of employment through the development and utilization of its own resources and comparative advantages.

While this report stresses the importance of invention and innovation, certain cautionary statements should also be made. There is an implicit assumption in certain recent statements that, with proper R&D, lagging industries such as textiles, fisheries, and railroads could become growth industries, that the only thing lacking is technological innovation. Without increasing demand, it is difficult to introduce technological innovation, especially in industries with very low demand-price elasticity, such as textiles and food. It is much easier to embody innovation in capital investments when these investments have to be made anyway, to meet a rising demand, than to replace obsolete equipment. This is part of the "chicken and egg" question dealt with in the work of Schmookler[14] and others, i.e., the question of whether demand leads to technological innovation or technological innovation leads to demand. The maximum impact of R&D lies in industries such as electric power and communications, where the demand-price elasticity is very high and there are also large economies of scale.

It should also be recognized that the economic problems of a depressed region with a large surplus of unskilled labor are often more susceptible to solution via the introduction of a technologically unsophisticated, labor-intensive industry than by the attraction of a high-technology industry calling for skilled manpower. The undeniable validity of the above assertion has led some authorities to the generalization that "such regions don't need R&D, they need entrepreneurs." There is little doubt that the improvement of a depressed economy calls for a variety of highly motivated entrepreneurs and innovators; this is one of the central conclusions of this report. Furthermore, such entrepreneurs may help the economy by introducing labor-intensive industries with relatively small R&D components. At the same time, if we define R&D to include efforts to survey the problems and opportunities in a region, to develop plans for the short-range solution of such problems, as well as to identify the long-term needs and potential strength of a region, such R&D activities can contribute significantly to both short-term and long-term economic regional well-being.

Delineation of Regions—Place Prosperity versus People Prosperity

Any discussion of regional development brings forth the question, "What constitutes a region?" This Committee has recognized that the problems of rural Appalachia, which includes a major portion of the areas of 13 states, have many similarities to the problems in the core centers of our metropolitan areas. Neither Appalachia nor portions of Los Angeles and Washington share in the affluence of the nation as a whole. In a sense, therefore, each of these geographical units represents a depressed region.

However, the Committee feels that to designate pockets of low economic opportunity, either urban or rural, and to try to find solutions to their problems in isolation from adjacent areas that are part of the same geographic or otherwise defined social or economic region is to limit the attainment of viable economic solutions. In a society in which metropolitan areas, in particular, have attained significant comparative advantages, particularly with respect to the location of high-technology industry, it seems essential to designate regions in a sufficiently large context to permit viable economic relationships.

Thus, regional delineations should recognize the essential interdependence of urban centers and rural hinterlands (and the central cores of cities with their metropolitan areas). Since the regional pattern of relationships is in a state of continuous change, we hesitate to propose a single national pattern. Nevertheless, throughout this report the Committee uses the term "region" to connote large multi-state regions sharing many common economic, social, and political ties and with a common set of important urban areas as their centers. In some cases, the term "region" is applied to designated areas such as the Four Corners Region or the Ozarks Region as set forth in congressional legislation establishing multi-state or multi-county areas for special federal help. The Committee believes that sound national policies for regional development require that those designated regions that do not include metropolitan centers be re-defined in order to make a sound approach to development possible.

The Committee recognizes that, while certain broad national objectives for regional development may now be formulated, these have not as yet been crystallized as stated national policies for regional economic development, either in terms of a regional geographic pattern for the nation as a whole or in terms of specified national priorities. Such larger issues go beyond the scope of this Committee's charge. However, the Committee has inevitably been faced with certain questions that relate to the broader national issues.

Thus, we have recognized the distinctions between place prosperity and people prosperity and the conflicting priorities that may sometimes be involved in dealing with regional problems. There are inevitably some areas or communities for which the comparative economic advantages have been adversely affected to such an extent that to maintain the objective of place prosperity is simply not in the national interest. The movement of people across regional boundaries in response to economic incentives is an accepted facet of our national life. At the turn of the century, the town of Aspen, Colorado, became a depressed area with the depletion of the local silver mines. Then, after the sources of income or employment disappeared, the town was no longer depressed: it was simply vacated. In recent years, it has assumed a new prosperity, again associated with the nearby natural resources, but totally unrelated to its former enterprise. Thus, a region is considered to be affluent or depressed mainly in terms of the affluence of the people who live there, and these may change significantly with time and circumstances.

Clearly, the provision of added mobility to segments of the population is one way of altering the economy of a region. It may alleviate an economically depressed region without enhancing its growth, or it may transfer the economic problems from one region to another, as with the migration of underemployed agricultural workers in the South to the slum districts of major northern cities.

Thus, a commitment to regional economic growth should not be construed in a narrow parochial context. A broad national policy for regional development must take into account not only the validity of population mobility but also the concept of localized decision-making as to regional priorities. At the same time, a representative democracy must establish national policies that entail a concern for the well-being of the individual regions as well as that of the nation as a whole. In the final analysis, regional economic development is an issue when the community leaders and/or the political leaders in a given region define it to be an issue. In making this decision, they have taken a first essential step toward alleviating existing regional problems or toward anticipating the solution of future problems.

Chapter II

Characteristics of Regional Growth—Regional Economic Implications Associated with the Location of R&D Institutions

Some Characteristics of Regional Growth and Industrial Location

In an open and growing economy, varying rates of regional and community development are inevitable. Some areas are much more attractive for certain types of industries and kinds of people than others; locational decisions tend to be based on such comparative advantages. On the whole, such decisions, and the shifts they entail, are important in generating improvements in productivity and in incomes.

An industry will choose a location for its productive activities—normally when it wants to increase the volume of its output by substantial amounts—by picking a site that will enable it to operate at the most profitable level. Production costs and revenues differ from one site to another, depending upon variations in access to basic inputs and markets. Sometimes access to inputs is dominant in determining the location of an activity, and sometimes market access; sometimes neither is dominant, with the result that location would be intermediate or indeterminant. This has led economists to characterize production activities as being input-oriented, market-oriented, oriented to intermediate sites or, when none of these apply, as "footloose."

In recent years, important shifts in the national economy have taken place, and these in turn have had profound effects on the economy of various regions. As Harvey Perloff has very plausibly indicated:

A highly important factor for the growth of areas has been the fact that the primary activities—farming, mining, forestry, and fishing—which are largely oriented to natural resources inputs, have greatly declined in *relative* importance. The location of manufacturing activities, while in some cases still tied to raw materials or semi-processed inputs, increasingly have become market-oriented. "Tertiary" or service activities—dealing as they do with such functions as transportation and communications, construction, trade, finance, government, the professions and recreation—are by and large closely tied to markets.

The industries which during the past decades have had the greatest relative growth have in very large part been of the market-oriented type or footloose.[21]

The impact of mechanization and automation has been, on the one hand, to accelerate the trend to tertiary or service industry and, concomitantly, to accelerate the trend toward urbanization. There has been a trend, as the manufacturing process has become more and more complex, toward the agglomeration of industries and services that depend on one another for their continued productivity. The tremendous growth of metropolitan areas and, in particular, the tendency for R&D activities to aggregate in these centers have been characteristic geographic features of modern economic development.

Many regions aspire to a "high-technology" economy, which has come to be regarded throughout the country as synonymous with growth and prosperity. There is a belief that federal science funds and the placement of federal science installations can help regions attain that goal. This belief requires some examination.

In the national economy, most employment growth is within two sectors:

The service sector, including education, health services, government, which between 1950 and 1960 provided almost exactly the number of new jobs (9 million) required to employ the total increase in workers entering the labor force.

"High-growth" industries associated with a high level of input from research and development (though proportionally these account for a small fraction of the labor force—see Chapter V).

There is a correlation between the location of service employment (i.e., metropolitan centers) and the location of so-called high-technology enterprise. A review of the evidence indicates that the rapid-growth regions, which include the concentrations of technology-intensive industries, are also the regions with high research and development expenditures and concentrations of scientists, engineers, and technicians.

The regions of the United States in which the availabilities of urban services and amenities are limited are also the regions deficient in high-growth, high-technology enterprise. Yet many metropolitan centers within these regions, proportionate to population, have their "fair share" of such activities. There appears to be a correlation between lack of urbanization and an underdeveloped economy.

Appalachia is a case in point. This large region is only 40 percent urban, compared with 70 percent for the nation. In 1960, 60 percent of the national labor force was engaged in service employment; in Appalachia only 50 percent was so engaged. One third of the Appalachian labor force is employed in manufacturing, while only one fourth is so engaged in the United States.

Between 1950 and 1960, national employment grew substantially, by 14 percent. Appalachia suffered a decline in employment during the same period, typified by its deficiencies in service employment. Studies of the economy of Appalachia have shown that it is characterized by substantial base-industry employment, which is serviced to an unusual degree by service industries outside the region. Appalachia lags behind the country in another way. Although it has more than its proportionate share of the nation's manufacturing, its share consists of the slow-growth industries. In 1954, value added per worker in manufacturing in Appalachia was almost 10 percent below the national average. By 1963, it was more than 20 percent below.*

Two main problems confront regions such as Appalachia in attracting and supporting a high-growth, technologically advanced economy:

Finding techniques for accelerating their urbanization and taking advantage of the growth opportunities provided by service industries in such centers.

Developing, in addition, the network of institutions and attitudes required to support an advanced economy.

As is indicated in the following section, the factors that affect the development of a modern technologically based economy are not related simply to the level of R&D activity, but involve the entire regional or community environment.

Factors Affecting the Introduction of High-Technology Enterprise

In the development of an advanced economy, technology is usually perceived as an important stimulant, if not an essential ingredient. However, high-technology enterprise can not be a stimulus to a region's economy; indeed it can not even be brought into the region unless a number of other factors are present:

*Ralph Widner, private communication.

Social and cultural factors. A region must have incentives for the utilization of technology in the solution of major problems as well as patience with regard to the time required. If it is to be willing to invest in high-risk, delayed-payoff ventures, a society must have both social stability and future-orientation. Whether or not a given community includes scientists and development engineers, it must contain a significant professional labor force. In order to attract or to retain talented professionals, the region must provide an inviting cultural environment as well as a pleasant physical environment.

Human resources. The incorporation of new technologies typically implies that old ways of doing things must be modified. This calls for intellectual adaptability among individuals and a hospitable intellectual climate in the communities in which they live. Thus, the provision of a well-articulated, broadly based system of primary, secondary, and higher education is a basic prerequisite for a high-technology economy. Technical skills are called for at both the professional and the non-professional levels. Increasingly, the rapid rate of change associated with the incorporation of technology in the nation at large suggests the need for the continuing acquisition of new skills and continuing education throughout individual careers.

Political factors. Frequently the most important influences upon regional development are social and political in origin, since they may determine whether innovation and change are to be sought or are powerfully resisted. To paraphrase a remark by Paul Hoffman, "Technological know-how can not be exported; it must be imported." A region must provide political leadership as well as a framework for the constructive interaction of individuals and institutions to attain regional goals.

The availability of venture capital. Although capital can flow across political boundaries with ease, and there is a great amount of risk capital available in the United States, it is nevertheless true that lenders often are reluctant to invest in distant enterprises. In particular, the small entrepreneur must usually rely upon local sources of capital. Lagging regions are often limited by the reluctance of their lenders to participate in high-risk, high-technology enterprise.

Natural resources. The availability of, or access to, natural resources has traditionally been an important ingredient in a region's economy. Indeed, the character of its agricultural and mineral resources was the key factor that historically differentiated the economy of one region from another. In recent years, new technology applied to the extraction industries has critically affected both the methods used and the job opportunities, typically reducing the manpower required. Thus, to attain optimum economic value from the availability of basic raw materials the region must attract value-adding processing and other "linked" manufacturing industries that relate to these resources. Alternatively, R&D may be incorporated either in the extractive or transportation phase in order to provide a comparative advantage over other sources of raw materials.

Physical environment. Geographically, most growth in the United States during the past two decades has occurred in the so-called "amenity regions," primarily those with pleasant climate. There is little doubt that the physical attractiveness of such communities as Phoenix, Denver, or the San Francisco Bay area has been a major factor in affecting the decisions to locate new high-technology facilities or to enlarge existing plants in those metropolitan areas. Since the critical resource in many professionally dominated fields is the availability of highly trained talent, access to the amenities of pleasant living may override other locational considerations. However, man-made features of the physical environment have played an increasingly significant role. Air-conditioning, for example, has made a major change by helping to offset some of the disadvantages of a hot or humid climate in some regions. It is a prime example in which widespread diffusion of a technological innovation has substantially altered the comparative economic advantage of regions. Other technological developments have similar profound effects on the environment, either for better or for worse. The automobile has made possible access to pleasant residential suburbs, but it has also brought traffic congestion, air pollution, and ugly urban sprawl. These features of the physical environment greatly affect a community's potential for attracting or retaining highly mobile professional personnel. They are increasingly subject to man-made decisions.

In the above listing of human, man-made, and natural resources, it is interesting to note that financial and human resources are relatively mobile and can be imported into a region if there is motivation to do so. By contrast, natural resources and state political structures are geographically fixed. Like the forests and fields, the political leaders in a given state or region are tied to the geography of their constituencies.

In addition to the above general factors, the development of new enterprise is typically dependent on entrepreneurship—on the innovative leadership of unique individuals or groups of individuals. In the Committee's review of many instances in which regions or communities succeeded in revitalizing their economies, it was possible in virtually every case to identify some key individual who played a particularly vital role. In other words, even when many of the other factors may be available, it takes the entrepreneur, the social inventor or innovator, to recognize the opportunities.

From the above discussion, it is apparent that by itself, federal science policy can not guarantee a given region an economic payoff. While the incorporation of modern technology can be a vital stimulus to the economy of a region, this cannot be effected in the absence of other significant factors. When such factors are present, they are conducive not only to the economic development but also to the general improvement of the quality of life in a community.

Regional Economic Implications Associated with the Location of R&D Institutions

The term "R&D institutions," as used here, is meant to denote the establishments and organizational entities that are directly charged with the performance of R&D. R&D institutions include laboratories and test facilities of industrial, governmental, university, and non-profit organizations, establishments engaged in analytic studies and a large range of establishments not designated as laboratories but engaged in the development of new materials, processes, and devices, e.g., electronics divisions of major companies.

Local and regional political leaders, public utilities, chambers of commerce, and other development organizations have traditionally acted as agents for the encouragement of various industrial and other employing organizations to locate within the vicinity. In recent years, there has been a growing concentration in the efforts of such groups to attract R&D establishments of all kinds to their communities. This has occurred despite the fact that R&D institutions in themselves do not necessarily encompass large numbers of jobs. It is evident, therefore, that the efforts to attract industrial or government-supported R&D organizations are based on strong beliefs that they have a large positive effect on the long-term economic development of a region. Recent examples of this interest and the extent of efforts devoted to it are found in the events leading up to the decisions to locate the 200 BeV accelerator in Weston, Illinois, and NASA's Electronics Research Center in Cambridge, Massachusetts.

To analyze the ways in which R&D institutions may affect the economic development of regions in which they are located, it is convenient to group the economic implications into three main categories:

The creation of effective demand—direct employment of laboratory personnel and the purchases that are made locally by the R&D installations and their employees.

The effects of the R&D installation on the ability of a region to attract or generate new industry—an environmental asset that, like good water or transportation, enlarges the potential of a region for further development.

Giving rise to new enterprises—as a result of the R&D performance by the installation.

1. Direct Economic Effects (The R&D Institution as a Generator of Effective Demand)

Of the above three categories, the contribution to immediate effective demand is the most obvious and direct. The payrolls associated with employment and the purchases made locally are translatable into local rounds of spending and the generation of additional local employment as a result of this spending. In this regard, an R&D organization is much like any other organization: its direct local impact depends on payments to its employees and on the amount of purchases that are made locally.

Few enterprises over the past 40 years have been more dependable in their contributions to the local economy than universities, central laboratories of large industrial corporations, and many federal research laboratories. In contrast, some of the major development programs, particularly in the military-space area, have resulted in more volatile impacts. One congressional committee studying these economic impacts reported the following:

> During its visit to Ogden, Utah, another community whose economic life depends mainly on one defense-space-oriented company, the committee saw the sad spectacle of snaggle-toothed streets—every other or every third dwelling in a certain residential area unoccupied. The explanation was failure of the company to receive renewal of research and development contracts from one of the large Federal agencies.[22]

Thus, there are wide variations in the continuity and character of the economic effects of an R&D institution, depending on the nature and work of the institution.

In addition, there is a significant variation in the direct economic effect depending on the character of the community. Where a highly developed supporting industry exists in the area, relatively large proportions of the subcontracts awarded by a prime R&D contractor are performed in the area. Such is the case in large R&D complexes, notably Boston and Los Angeles, where the local "employment multiplier" of R&D work is quite high.

In other communities, such as Seattle and St. Louis, where supporting technical industry is less highly developed, a far greater share of the subcontracts is awarded to firms outside of the area. This "leakage" reduces the size of the local employment multiplier resulting from the award of an R&D contract to a local firm, compared with other activity in the region or with other R&D centers. There seems little doubt that a dominant position of one industrial corporation in a given region tends to decrease the external multiplier effect. For example, in a study[23] made of the urban employment multiplier of new jobs in the aerospace industry in St. Louis, a city in which there is one major aerospace firm, it was found that the local employment multiplier for the aerospace industry was only 1.8 as compared with a multiplier for other industry in St. Louis of approximately 2.5 and for the military-space industry in Los Angeles of 4.6.

2. Social and Political Effects

Some of the most profound effects of R&D institutions on a community may be found in their social and political impacts. In a study of the defense R&D industry in Denver, Tucson, and Orlando, it was found that:

> In each of the areas the managerial and professional workers and their families appeared to take a relatively active part in the civic and cultural life of the community. . . . Substantial pressures for improvement and expansion of school curricula had been brought to bear on the public and private schools of the area.... In one suburban community in that area . . . there had not only been an increase in the number and quality of courses offered, but employees of the company had been elected to the local school board.[24]

A study of a large federal R&D facility in Tullahoma, Tennessee, provided further specifics:

> The impact of the Arnold Engineering Development Center (AEDC) on Tullahoma . . . in terms of new industrial jobs had been slight in the 14 years of the center's existence at the time of the Committee's study (453 new jobs, of which only 28 were related to R&D), but the impact on the local educational system had been profound. . . . In 1963 the local superintendent of education for Tullahoma received a salary surpassed, in Tennessee, only by those of the superintendents of Memphis and, significantly, Oak Ridge. One third of the teachers in the Tullahoma school system are members of the families of AEDC employees.*

The social impact of R&D institutions on their local communities is found in the entry of newcomers (comprised of a relatively high percentage of scientists and engineers and other professionals) into many aspects of the cultural and political life of the communities in which they are living. They have been particularly involved in organizations classified as hobby, cultural, and recreational.

The presence of more than one R&D institution within the community, particularly in smaller cities, is of significant economic and social value to the individual scientist or engineer. It is of considerable worth, particularly to the younger man with a family of growing children, to be able to seek employment in another firm without having to move to another community.

Large numbers of higher-income engineers and scientists also change the local pattern of demands for consumer goods and public services. One effect

*Al Shapero, private communication.

is a rise in the local wage structure, thus increasing both incomes and living costs.

On balance, the R&D institution typically is seen as a desirable social and cultural factor in the community. This is particularly true of universities, in which the social and cultural advantages are associated not only with the professional level of employees but also with the function of the institution itself.

3. The R&D Institution as a Generator of New Industry

The recent history of industrial development includes many examples of industries and corporations that are direct outgrowths of research and development. New corporations have been formed and older companies have gained new impetus from the development of such new technologies as solid-state circuitry, ultra-high vacuum, microwaves, and nuclear reactors. Some new enterprises have been initiated by groups breaking away from older industrial corporations or government laboratories; some have been initiated by university professors.

The role of the university as a generator of industrial development has occasioned much discussion. The spin-offs from the laboratories of MIT and Stanford University have been dramatic. Nevertheless, there is little systematic basis for concluding that a university with strong engineering and physical sciences departments and large R&D laboratories will inevitably generate new local R&D industry or even that it is essential for such a development. The university can contribute substantially, particularly in enhancing the social and cultural attractiveness of a community and providing education at various levels of undergraduate and graduate work. In regions of the country in which industrial complexes (civilian as well as military-space) have developed in the absence of institutions of higher education, strong pressures have since developed for establishing new universities or building graduate programs in existing institutions.

Universities associated directly with industrial spin-off have provided not only a cultural and educational contribution but also often key entrepreneurs. However, relatively few academic institutions have encouraged students or faculty to venture into the commercial world with academically derived products or ideas. Nor are the attitudes or policies of many institutions favorable to the formation of companies by employees of universities.

In this context it should be pointed out that encouraging entrepreneurship among faculty members and graduate students is not always an unmixed blessing. It may well confer direct economic advantages on a region, and in some cases it undoubtedly has; but it also tends to distract faculty and students from their main educational missions and to create divided loyalties on campus. The spirit of entrepreneurship and involvement with the outside world is likely to be of great value to the society that supports higher education, but it is less likely to encourage the deepest scholarship or eminence in basic research.

Industrial spin-off has occurred also from government laboratories, not-for-profit corporations, and established industrial laboratories. The conditions under which it is likely to occur are as much characterized by communities as by the parent institutions. For example, relatively few spin-offs have occurred in cities dominated by single major corporate enterprises. Such communities seem to lack factors essential to the encouragement and survival of newly formed technological enterprises, nor are there many alternatives, such as re-employment opportunities, available to entrepreneurs in the event of failure.

In many cases, the particular stimulus for the formation of a new enterprise is the imposition of institutional obstacles on the individual in the course of his commitment to a new idea: for example, the cancellation of his employer's major contract, or frustration with the failure of corporate management to accept a new idea. Since the spin-off of new corporations from existing ones is seldom considered a successful accomplishment by parent companies, this source of new enterprise is generally underemphasized.

4. How Does an R&D Complex Develop in an Area?

How an R&D complex is developed has intrigued many individuals and perplexed numerous communities. From the studies available, it appears that no one factor or circumstance can be singled out as dominant. The presence of individuals with entrepreneurial skills and the availability of venture capital are often emphasized. A set of studies of military-oriented R&D complexes by the Stanford Research Institute yielded the following findings:

> An essential process in the transformation of a community into a defense R&D complex is an increase in the number of local contractors with or without a parallel increase in the dollars awarded, to provide a multiplicity of potential growth points.
>
> . . . a larger number of prime contractors means a larger number of managements making technical decisions from independent viewpoints, thereby increasing the probability of achieving technical variety. The presence of a large, locally dominant defense R&D establishment does not provide the conditions required for an increase in the number of local prime contractors. Domination by one organization may even be considered a negative factor.[25]

The nature of the market for the larger corporation that functions as a prime contractor for defense, space, or other major federal development programs differs substantially from the market for the smaller firm. The large company is often a prime contractor and is relatively independent of its local environment with regard to access to its market, sources of material, and financial support. Indeed, it is often found that the large defense R&D company is independent of the local financial community for both its equity and its working capital requirements. In contrast, a small R&D company is usually highly dependent on its local financial community. The small defense company is primarily a sub-contractor and its markets are the large defense prime contractors or the major sub-contractors. It must seek out the market wherever it is located, and bid competitively within it. As a consequence, its cost of sales and sales effectiveness are much more critical to its performance than are those of the large company. A local environment that aids in lowering the cost of sales may be critical to its existence; a significant factor may be the number of defense prime contractors in its immediate vicinity. The small R&D sub-contractor often provides very special services or products. It tends to hedge against market uncertainty by locating in a large defense complex where it can have continuous access to a number of potential customers. Furthermore, many sub-contracting efforts in small companies are done on development contracts in which informed, word-of-mouth interchange of information tends to be the most effective mode of communication.

These considerations emphasize the advantage of a community with a multiplicity of prime contractors and sub-contractors. The community that first attains the status of a major high-technology complex has a natural advantage over the area with only a single large prime contractor. Thus, we find little collateral R&D industrial development in Seattle and St. Louis, each of which is dominated by a single, large, prime contractor performing advanced defense and space R&D work valued at billions of dollars.

The question of whether an R&D complex has more to offer a community in terms of economic development than do other kinds of industry is still an open one, but one that is worthy of more rational consideration from a national policy viewpoint than it has received generally to date.

Chapter III

Characteristics of R&D— Incorporation of Science and Technology into the Economy

The Overlapping Nature of R&D Activities–Some Definitions and Concepts

In the context of an evaluation of national policies in support of these activities, it is essential to recognize and to clarify the differences between science and technology or between research and development, and the manner in which they relate to each other and to economic development.

For most human history, science and technology were separate enterprises with differing objectives and conducted by different individuals and even different classes of people. The relation between science and technology was traditionally quite loose, and applications of science to technology in many areas historically were quite casual. Only in the course of the twentieth century and, in particular, since World War II has there been a deliberate effort to apply science to technology on a broad scale. In view of this relatively recent development in human affairs, it is not surprising that many problems exist–not only in the management of science and technology but in broadening the public understanding of these activities and of their relationships to each other and to society.

Science, in this context, is more than the classification of facts and observed phenomena; it is the rational correlated knowledge of natural phenomena. Technology consists of codified and reproducible ways of doing things; much of this is based on systematic theoretical knowledge, i.e., science, but some is based on codified experience, i.e., technological "know-how." Thus, technology includes any tool or technique, any product or process, or method of doing or making, by which human capability is extended.

While the terms "science" and "technology" are sometimes used to include the acts of seeking new knowledge or of developing new methods for doing things, these efforts are more aptly designated by the terms "research" and "development."

A principal difficulty in characterizing research and/or development is that these embrace a set of overlapping activities that do not have sharply defined boundaries and in which sharp distinctions often are counter-productive within an organization dedicated to relating one set of activities to the other. Even widely used designations such as "basic research" and "applied research" are not without ambiguity. Basic research is often defined as being aimed at extending knowledge without conscious regard to application; research undertaken with a particular application in mind at some not-too-distant time is classified as applied research. Among the difficulties in such a division is agreement on what constitutes the not-too-distant future and what constitutes the motivation for doing the work. Frequently, the motivations of researchers are more mixed than such a separation would suggest. Furthermore, a given research activity may be properly thought of as basic research by the performer and, at the same time, as applied research by the sponsor, or *vice versa*, depending on the subjective assessment of its relation to potential applications.

Under these circumstances, it makes sense to recognize a wide set of related activities and, at the same time, to admit to important distinctions between research and development. At one limit of the spectrum of activities lies basic or scientific research, an activity in which the principal motivation is to strengthen the conceptual structure and expand the scope of man's knowledge. This in no way implies that it will not find application, sooner or later, in various devices, processes, or systems; rather, such research does not have application as a principal goal in its pursuit. At the other limit of these activities, development is used to designate activities directed toward the application of existing knowledge, toward the design of devices or processes useful to man.

Applied science occupies an intermediate position between pure science and engineering development. In applied science, we may have a definite practical aim in mind; however, we are uncertain as to whether this aim can be accomplished. To find new, fruitful applications of pure science is in itself a creative process. In some cases, the immediate objective of applied science may not be a specific device or process but, rather, better understanding of a field very closely related to technology; it would probably not be worth undertaking purely for the sake of intellectual curiosity. Alternatively, new developments frequently require new details of knowledge or conceptual structure that can be produced by scientific research techniques. The applied research aimed at such insight is not the stimulus to innovation but supplies vitally needed information in support of it.

In characterizing the two distinct limits in this continuous range of activities, we observe that basic research is aimed toward a philosophical or analytical description of natural phenomena, whereas development is focused on a need or a problem posed by society. Basic research is considered as worthwhile if it contributes to our understanding, whereas development must be judged in terms of the need for its product.

Characteristics of the Scientific Community–the Relationship of Basic Research to Institutions and to Society

In this discussion, we include not only basic research in the natural sciences but also in the life sciences, in which it is now making profound changes, and the behavioral and social sciences, in which basic research is beginning to have a significant impact on related professional and applied fields.

Basic research begins with the selection by an individual investigator of a problem or problem area from among the vast variety of natural or social phenomena. The ultimate validity of such a selection depends not only on the significance of the problem but also on its tractability; clearly, both the choice of problem and the approach to its solution are based on subjective evaluations by the individual researcher. Ultimately, however, the evaluation of both the validity of the solution and its significance are the responsibility of the larger community of specialists in the field.

Since the findings in any one investigation may be fragmentary and elucidate only one small aspect of the problem area, the challenge in validating and confirming the significance of the individual scientist's contribution is increasingly complex. It is a triumph of the value and reward system in scientific research that it has drawn upon the efforts of a remarkably individualistic set of practitioners and molded them into nationwide or worldwide communities that have succeeded in many areas in relating a large reservoir of isolated contributions into a fabric of viable understanding. The dynamics of the "system" of scientific advance have relied very heavily on an elaborate system of public documentation, with strong sanctions operating on the individual scientist to make full use of and give proper credit for previous work relevant to his own. Discovery and innovation within science have extremely rapid diffusion times, and the rate of diffusion is influenced to only a minor degree by political and organizational boundaries. Thus, the scientific research community, functionally organized by separate disciplines, is worldwide in scope, and well-established communications exist.

With the increasing complexity both in the structure of science and in the experimental instrumentation needed to gather further data, the nature of the individual's relationship to his discipline has depended heavily on the nature of the local community in which he works. In view of the rapid advances in his own and related fields, it is increasingly necessary that a researcher be in contact with a group of his peers on a day-to-day basis. Thus the character of his local community is crucial to success; the critical mass for a given research group depends on the complexity and rate of development of the field. The worldwide community is made up of a relatively small number of outstanding centers, which set the standards of performance and provide the foci for communication. The interactive relationships within the truly outstanding research centers help to explain the quality of individual performances. A corollary of this is that brilliant individual researchers are seldom found in a community of second-raters. The search for individuals possessing unusual scientific or technological talent is also a nationwide or a worldwide activity. Unusual talent occurs at random, is hard to detect, and must be carefully nurtured and developed. After an outstanding individual has been discovered and his talents recognized, he has very great mobility; it is easy for a gifted scientist to move from one research center to another almost anywhere in the world.

Because modern technology depends increasingly on the scientific knowledge that has been accumulated, it is understandable that society places considerable value on the products of scientific research. However, it is very important to differentiate between the product values associated with the collective efforts of the national or international community of science and the product values of given scientific investigations. Although incremental insights and data are added to the reservoir of knowledge by individual investigators on a continuing basis, it is most problematical as to when a given contribution to knowledge may find application. Frequently, a result may lie unused for decades before certain additional insights or techniques incorporate the result into a useful product. Because ideas fit into a structure of knowledge in a complex and interrelated way, it is often extremely difficult to trace back the particular fundamental ideas that contributed to a practical application. In any case, it is virtually impossible to attach a value to the incremental scientific contribution at the time it is delivered, and even more so when it is merely proposed as an idea.* Furthermore, it is hard to predict whether a given increment of new knowledge will be useful to the institution or agency that sponsored it; it may, indeed, be of greater value to another, perhaps competing, institution. For these reasons, although basic scientific research can be viewed as having collective *product values* for the nation as a whole or for a program with national scope, it is unrealistic to think in terms of supporting a given scientist on the basis of the practical value of his "research product." It is for these reasons that institutions that support science typically recognize as

*As pointed out by Harvey Brooks (private communication), these statements apply not only to application to technology but also to application to science. Not only is it hard to determine when a given contribution may find practical application, but it is also often difficult to evaluate the significance of a basic discovery or advance until after other parallel advances or discoveries have been made.

a principal justification the *process values* associated with the research activity, i.e., the values associated with the research activity viewed as a social, cultural, or educational process.

The principal process value of research in the university is its value in the educational mission itself. Not only does the research activity relate in a direct way to the education of graduate students but also to the continuing education of professors and, less directly, to undergraduate education. Similar process values provide an economic justification for basic research in industry; for example, an ongoing research program constitutes an excellent way of recruiting and developing technical talent for future leadership roles. In addition, the basic scientist in a profit-making institution may aid in establishing a desired intellectual environment. He is able to bring into a proprietary situation the standards of performance and technical achievement that are characteristic of the scientific community as a whole. Finally, a basic science effort can provide for applied programs *a window on the world's research effort.* Basic scientists often spend a fraction of their time consulting in their areas of expertise with problem-solving groups. Thus, the typical scientific researcher includes, along with his basic commitment to research, professional activities like teaching, consulting, or advising, which have values to his institution other than the direct products of his research.

The Nature and Organization of Applied Research and Development

1. Objectives and Organization

It is largely through development and applied research that new and improved products, better processes and more effective systems are made available to society. Thus the activities in these categories are identified immediately with their product values; however, they fall into a very wide variety of professional pursuits and technological objectives. Intertwined in all these is a need for invention to bring new technology into being. The diversity of objectives and activities can perhaps be illustrated by listing a series of hypothetical applied technological activities as follows. Because of the availability of approximate data, the examples are taken from the field of air transportation; for each program a rough estimate of the possible cost is given.

a. Develop a prototype supersonic jet transport plane—$1,000,000,000.
b. Develop a prototype jet engine for the above—$100,000,000.
c. Analyze and solve a problem involving metal fracture on a specified airplane component—$1,000,000.
d. Carry out analytical study of shock waves as a function of distance from supersonic sources—$100,000.

e. Carry out a market analysis of supersonic jet transportation for an airline company—$100,000.

f. Make a systems analysis for the location of an SST jet airport for the State of Illinois—$100,000.

The above list is intended to demonstrate the wide variety of activities that fall into the categories of applied research and development. It includes a large-scale hardware development procurement that might involve 20,000 or more man-years of effort, a systems-engineering analysis involving technological problems, and a systems analysis including socioeconomic inputs.

All the above activities illustrate the fact that applied research or development must be focused. In many applications such work may have a regional or localized implication. Unlike basic research, the objectives are typically clearly defined and the criteria for success predetermined. Very frequently, the time schedule for delivery of the final product is crucial, particularly when the over-all system is dependent on the successful development of various sub-systems. To reduce the uncertainties inherent in new processes or techniques, the prime contractor frequently takes several technological approaches in parallel.

As contrasted with research, applied programs draw upon a variety of disciplines, the particular requirements being imposed by the nature of the problem. A given application is typically motivated by a single need and draws from a large body of knowledge. The characteristic mode of interaction of people engaged in an applied program is that of a team. The nature of the team is a function of the complexity of the problem and the urgency of the imposed completion date. If the system involves hundreds or thousands of interrelated technological developments, it is clear that a team of large size and sophisticated relationships is called for. Recent military and space systems have utilized new managerial techniques and laboratories of very large critical size. On the other hand, systems analyses of some complex problems can and have been carried out with small numbers of broadly educated individuals.

Development typically calls for knowledge from many subject areas. It is the specific problem to be solved that determines the varied talents and backgrounds needed to make up a given team, and its success depends critically on the quality of team leadership and the relationships built up between the individuals within it. A team assembled to carry out a given development is seldom uniquely suited to carry out a task in another area. Hence, the success of a development organization depends on its capability for restructuring new teams for attacks on new problems.

Whereas discovery and new insights within science are communicated readily across political or organizational boundaries, in the case of development and applications research the communications pattern tends to be more confined to organizational channels and to be more localized in character. One reason for this is that much technological insight is based on intuitive invention or "know-how"—it is more difficult to verbalize and to document. Another reason is the requirement in some cases to retain proprietary information as a company or national asset. Thus, typically, the technologist in an industrial or mission-oriented government laboratory tends to be oriented toward internal communications and (unlike the scientist in such institutions) to seek recognition and reward within the organization. Increasingly, however, there is a trend in the direction of greater conceptualization of technological knowledge and documentation of specific advances. (It is important to note significant differences in the degree of conceptualization of technological knowledge in different fields. In general, the more closely a field of technology is related to recent or contemporary science, the more likely it is to acquire the documentation habits of science.)

The administrator, either at the institutional or project level, plays a more important role in development (or applied research) than is the case in basic research. He must be concerned not only with the technical substance of the work but also with the scheduling and assignment of responsibilities in what is typically a time-limited and cost-limited enterprise. Whereas the good manager seldom directs in the sense of telling people how to solve each problem, he must take a far more active role than his counterpart in basic research; he must see to it that each development team is adequately staffed and sufficiently motivated to carry through to projected solutions, even in cases in which the approach to the solution was "not invented here."

2. *The Role of Invention*

Invention is the process of bringing new technology into being, or the new technology created in the process. Historically, invention has not always come from R&D; in earlier centuries, it was more often based on intuitive insight or knowledge of the "tricks of the trade." Indeed, such terms as "well versed in the art" or "state of the art" are still a part of patent law. However, since the turn of the century and, particularly, in the past few decades, the more distinctive the new product or process, the more likely it is to have originated in the applied research or development laboratory. Scientific understanding as well as a knowledge of the cutting edge of technological advance is increasingly essential to the inventor, particularly in the sophisticated areas of modern technology. Thus, while laboratories for basic research were well established much earlier, organized invention is relatively recent. What Whitehead[32] has referred to as "the invention of the method of invention" took place in the form of the establishment of central "research" laboratories in a number of major industrial corporations in the early 1930's.

Science is a resource from which new technology derives. Not infrequently, inventions emerge directly from science or result from scientific discoveries or from instrumentation originally developed to improve scientific measurements. However, the application of science to technology and the utilization of science, particularly for economic purposes, increasingly depend upon institutions and attitudes that are different from those necessary for the creation of science. In particular, such application calls for institutions and individuals who look to the marketplace, to the production facilities, and to the problems posed by society for inspiration and reward.

In recent years, the problems posed by society have tended to be set forth in increasingly broad terms. Thus the pressing problems in transportation may be appropriately addressed in the general terms of "design a transportation system" or "design an air-traffic-control system" rather than in the specific terms of the design of hardware components. In addressing such problems, the social or political constraints are often as difficult to meet as the technological or economic constraints. Inventions that permit "designing around" or accommodating social obstacles call for as much social ingenuity as technical ingenuity; typically the two have to be combined in a single individual. In some cases, a solution is possible only if the innovator can bring about a change in such social barriers, e.g., changes in building codes or zoning restrictions.

In one sense, the idea of social barriers or constraints on technical invention is not new: virtually any new product or way of doing things must overcome traditional attitudes to meet the requirements of the market. However, with the growing awareness of the social costs of various technological developments—e.g., automobiles and their impact on air pollution or traffic congestion—there are social needs that are not taken into account in the marketplace. There is an increasing requirement for the articulation of such social needs in a way that encourages invention. In some cases, a technological invention may be the "key" that provides the solution to a problem with complex social or political constraints. In other cases social inventions—including new institutional or political frameworks—are required before technological solutions are feasible. In either case, the changing environment calls for inventors with both technological and social insight.

The Incorporation of Science and Technology into the Economy—Technological Innovation and Technology Transfer

The primary way in which research and development affect the economy is by increasing the productivity with which the nation's resources are used, notably through the development of new and improved products, processes, and systems. Even if technical feasibility should be proved, however, it is by no means clear whether a new idea or invention will lead to rewarding results in an economic or practical sense. The term *innovation* has been used to describe *the process by which new products, processes, or ways of doing things are introduced to widespread use* in the economy, the society, or into the process of government. It may be applied to many areas of human endeavor—to industry or agriculture, to medicine or education—and to a variety of social, economic, or political activities.

In many instances of innovation, one finds a dedicated proponent, a single-minded individual with a clear and unswerving vision of the goal that he sees as possible and desirable. Such an individual may or may not be the inventor of the new idea; he is the person who seeks and obtains financial support in the development phase, attracts creative people to the various activities required, and sees it through—if necessary—up to the production and utilization of a new product or process. In short, he is a technological entrepreneur.

Although the risk of failure of a new idea is less of a liability to a large company or federally supported laboratory than to a small enterprise that can not spread its risk over several such ventures, the process of innovation has many similarities, independent of institutional size or objectives. The individual innovator or entrepreneur must seek and obtain financial backing; he must be persuasive in changing traditional viewpoints and in overcoming inertia—frequently in the form of bureaucratic concerns about making "mistakes." Thus, the term *innovation* involves activities that are often different from *invention*, but in which creative ingenuity in dealing with a wide variety of issues is called for; the technological entrepreneur must understand not only the technology with which he is dealing but also the society into which he must introduce the new idea.

The term *technology transfer* has been used to describe *processes by which a successful development of technological know-how built up in one institution is embodied in a way of doing things by other institutions or groups.* It refers to the processes by which science and technology are diffused throughout human activity.

For historical reasons, we tend to view technology primarily in terms of machines and physical instrumentation, that is, hardware. However, today technology consists increasingly of "software," that is, the organization and systematization of ways of doing things, and not merely the ways of making things or the specifications for things themselves. Unless we take this wider view of technology, our policies and goals are likely to be based on an obsolete concept of the transfer process. In this view, we should include managerial technology or management systems. Harvey Brooks has emphasized the increasing importance of software:

It is necessary to take this broader view of technology because the process of technology transfer is similar, whether we are talking about hardware or software, and because non-material technology is the fastest growing, and is likely to increase in relative significance in the future.[33]

"Vertical" transfer occurs when new products or processes are carried through successive stages of research, development, manufacturing, and marketing in a given setting. It includes the process by which new scientific knowledge is incorporated into new technology. Many major advances, such as nuclear reactors, television, and transistors, have resulted from vertical transfer of technology and have called for highly structured and highly integrated research and development organizations. Even if the original idea were generated elsewhere, the nature of the product often calls for a large R&D organization. This characterizes the central laboratories of many large corporations, as well as the national laboratories of the AEC and NASA.

"Horizontal" transfer describes processes in which technological developments are transferred from one application to another, one corporation to another, one industry to another, or even from one region or country to another. Increasingly, the vertical transfer of new technology has been accompanied by horizontal technological transfer, even involving major new technologies such as the computer. Frequently, vertical technological transfer is aided by the contributions of small companies, often sub-contractors, which specialize either in hardware components or sub-assemblies or in technological software. The growth of an R&D industry, particularly the scientific-instrumentation industry, typifies the build-up of horizontal technological transfer.

Historically, one of the most important mechanisms for technology transfer has taken place in the marketing and purchase of capital goods. Thus, technology imbedded in machine tools was sold by that industry to the manufacturers of metal products; similarly, innovation in printing technology was sold in the form of capital goods to the publishing industry. This also typified the transfer of technology from one region to another, or from one country to another. Increasingly in recent years, capital goods must be considered to include not only hardware but software: it has been suggested that the equivalent of machine tools in this context might be called information tools. Software technology includes not only computer programs but also various techniques for controlling, testing, evaluating, or managing complex procedures and organizations; it also includes material and aids for the training of personnel in the use of new approaches.

Another important mechanism for horizontal transfer lies in the utilization of new materials. Such materials as synthetic fibers, plastics, metal alloys, composites and ceramics often are introduced into products far different from those for which they were originally developed by organizations other than the users.

The transfer of technologies developed by mission-oriented agencies of the federal government to other applications or agencies has been widely recognized. Thus, civilian industries have benefited greatly from such examples of transfer as turbine engines for aircraft, transistors and integrated electronic circuitry for computers, and many examples of electronic instrumentation.

It should be noted that the rate of technology transfer can be greatly affected by the manner in which the developed product is "packaged." The development as well as the transfer to other uses can be greatly accelerated if the device or process is recognized as a potential product of broader use rather than one that meets only a specific need within the sponsoring government agency; indeed, both the government use and the industrial application can be greatly benefited by stimulating private demand for the potential product. Conscious attention to the transfer of such technology from one agency to another would also enhance the payoff and potential for the originating agency.

Technological know-how and newly developed processes or techniques are often transferred via the physical flow of personnel from one institution to another, or by the movement of people between fields of science and technology, and from science into technology. Many aspects of new technology are not incorporated in written reports. Hence, the movement of knowledgeable engineers or scientists is often mandatory in transferring technological know-how from one corporation to another, or from a government laboratory to industry. People are often transferred to carry such know-how from the research to the development laboratory or to take a new product from development to pilot production in a given corporation. Consulting and advisory activities represent additional ways in which technology transfer is encouraged via personnel interactions. These mechanisms for technology transfer are summarized in the statement, "The technological pipeline is people."

Technology transfer is frequently activated by and associated with the marketing function, particularly in the process of finding entirely new applications for a product developed to meet a given requirement. The "applications engineer" is a relatively recent addition to the field of marketing; his activities are devoted to finding new applications for recently developed products. Certain high-technology industries, particularly those engaged in scientific instrumentation or high-speed computers, represent a relatively small fraction of the total gross national product in annual sales. However, they contribute in a major way to technology transfer since their rate of growth depends directly on the discovery of new applications for their products. A given product or process that is small in relation to the gross national product may nevertheless affect a wide area of productivity and may therefore have a major effect on the gross national product; e.g., a new method of prospecting for oil.

Technology transfer also is generated through entrepreneurial activities, in particular, the spin-off of new enterprise from existing organizations. Entrepreneurship is also closely related to the movement of people. Universities and research institutions often provide the training grounds as well as a form of interim personal security for would-be technical entrepreneurs while they are developing know-how and faith in a new idea.

Finally, *technology transfer takes place through the various mechanisms for the exchange of technical information* through the scientific and technical literature, through licensing of patents, exchange or sale of know-how, and through personal interactions. Opportunities for person-to-person exchange are provided by technical meetings and trade exhibitions, programs of training and education, and accidental personal contacts. The literature for technology transfer includes not only the archival technical journals but also trade journals, patents issued, and even advertisements.

This wide array of mechanisms for technological transfer emphasizes the diversity of activities and institutions that translate R&D into the national economy. This diversity will have its counterpart in the numerous facets of national or regional science policy when reviewed in the context of economic development. It is not possible to form a precise judgment as to the relative importance of these various mechanisms for the transfer of technology. The dominant mechanisms in a given instance vary with the nature of the technology, the industry, the resources involved, and other related factors. Obviously the various transfer processes do not operate independently of each other; an effective program or strategy for increasing the rate of transfer would need to combine a number of mutually supportive elements.

With respect to technologically backward regions, it would appear that there are deficiencies in horizontal transfer, particularly as implemented by the movement of persons skilled in advanced technology. This difficulty is heightened if there are differences in industrial structure among regions so that a desired movement of highly skilled persons into a given region would call for a transfer of their employment from high-technology to low-technology industries as well. Since it is difficult to provide incentives in the latter situation adequate to motivate outstanding technological personnel, it follows that technologically backward regions are usually called upon to attract new types of industry to facilitate technology transfer.

Chapter IV

R&D Activities Relevant to Regional Economic Development—Institutional Relationships

Direct Contributions to the Regional Economy through Development of New and Improved Products, Processes, and Ways of Doing Things

Research and development make their greatest direct contributions to the economy as sources of invention of new technology, both hardware and software. The institutions in which R&D aimed at such end products is carried out are typically mission-oriented laboratories, with a strong commitment to the solution of problems and the achievement of practical or economically justifiable objectives.

Industrial R&D laboratories constitute by far the largest single contributor of such efforts, although important programs committed to such goals are also located in each of the other major categories of R&D institutions: government laboratories, not-for-profit corporations, and universities. Industry is the largest performer of federally sponsored as well as internally funded R&D. Since its mission is, generally speaking, to enhance the long-range profitability of the parent corporation, the typical industrial laboratory is committed to one or more of four major phases of industrial innovation:

development of new products or processes for the marketplace;

improvement or reduction in costs of existing products to meet competitive pressures or to increase profit margins;

improvement or reduction in costs of manufacturing processes for more or less standard products; and

improvement of management techniques aimed at higher productivity or greater efficiency in corporate operations.

Aside from its locational impact, which is discussed elsewhere in this report, an industrial development laboratory may have a selective impact on the economy of a given region as a consequence of the development of products that make unique use of regionally located resources—especially natural resources or human resources.

Federally supported mission-oriented laboratories and in-house government laboratories have also made significant contributions to technological innovation. Though their initial commitment has typically been to products or problem solutions for which the federal government itself is the sole or principal customer (e.g., military-space vehicles, air-traffic-control systems), they have also carried out important developments that ultimately were to be marketed in the private sector, particularly in ventures involving high risks and high development costs. Examples are the development of nuclear reactors for electrical power or ship propulsion, the development of communication satellites and of jet aircraft engines, all of which have had important economic implications. In general, the federally sponsored laboratory is committed to a particular technological mission or the solution of a particular class of problems, however broadly stated—e.g., space flight, cure of cancer, weather prediction—objectives that can be readily associated with the sponsoring mission-oriented government agency.

The typical free-standing, not-for-profit institute, by contrast, contributes to innovation and to the economy by marketing its research or development competence in specified fields rather than by designating an over-all laboratory mission. Such laboratories as the Batelle Memorial Institute and the Stanford Research Institute operate as job shops for a very wide variety of sponsors; they work with clients from all sectors of the economy, from all parts of the country and many foreign nations. It is interesting to note that, although a number of such not-for-profit laboratories were established with a special view to the economic development of their local regions, the dynamics of their support—i.e., the marketing of R&D competence in a more or less open economy—has in almost all cases broadened into a functional relationship with sponsors on a national basis. In broad analogy to the Mayo Clinic or other well-known medical centers, the free-standing, not-for-profit research institute draws its clients not only or even largely from the local neighborhood, but from the nation at large. It specializes in those fields in which the institution has greatest professional talent, motivation, and research interests.

Although operated in the public service, these R&D institutions have made significant contributions to the profit-oriented economy through development of new technologies or products, particularly in areas in which risks were higher and payoffs longer-range than typically carried out within industrial development institutions.

Universities have also played a role in technological innovation and transfer. The classic demonstration is that of the colleges of agriculture and the agricultural experiment stations. In recent years, other professional schools, particularly colleges of engineering and of business administration, have played important roles. Important contributions have also been made by physics and chemistry departments, both in research on the forefront of applied science and technology and in their educational function. In addition, there have been important instances of invention and industrial spin-off, though these may well be more the exception than the rule. Advice by academic staff acting as consultants in an individual capacity to both industry and government has also resulted in significant contributions to the nation's economy.

The Development of Human Capabilities and Skills

If the development of new products and techniques is largely carried out by profit-oriented corporations, the development of human resources is largely associated with educational institutions. In no small measure, the regional problems of rural America and of the city centers are associated with the failure of local and regional educational policies and institutions to keep pace with national economic and technological development.

A key indicator of the educational potential in a given community or region is the fraction of the population that goes on beyond high school to institutions of higher education. While in some communities this fraction is very large and the national average is approaching 50 percent, it is quite small in economically disadvantaged regions or cities. The inhabitants of such regions are, in effect, unable to participate fully and to compete in the modern economy.

If the people who have been denied such opportunities are to receive them, there must be a national commitment to provide educational opportunities at all levels to all citizens, no matter what region they live in. There is need, first of all, for massive improvement in the earlier primary and secondary grades in providing adequate preparation for the poor and disadvantaged. Second, there is a need for providing quality institutions of higher education that are accessible to a larger fraction of the population. In addition, there is a challenge to provide continuing education, especially for those already displaced by technological innovation, and more generally for all elements of the professional as well as the labor population in order to keep pace with the accelerating rate of change that characterizes our society. A technologically based economy can remain socially responsive only if it adopts measures to continue and maintain a progression beyond earlier training and ways of doing things.

It may be a good thing to replace some obsolete school buildings with new ones, but it is much more important to recognize the need for fundamental changes to meet the needs outlined in the paragraph above.

It should be recognized, of course, that significant advances in the development of the human capabilities in a given region increase the mobility of these resources. In many regions or communities that are economically depressed, the provision of educational opportunities to develop new skills is often recommended as a stimulus to the economy. However, if this process is not to result in siphoning the most effective young individuals to more favored areas, the region must concern itself with the total environment for retaining them and attracting others.

National policies regarding R&D affect the above issues in two ways. First, the provision of adequate institutions and personnel for higher education is critically dependent on the availability of support for graduate education, which is increasingly bound to graduate research. Secondly, research and development are needed to bring innovation and change into the educational process at all levels. In view of their role in the training of teachers at all levels, changes and improvements in methods are uniquely dependent on the programs of the nation's universities.

In recent years, this country's universities have assumed leading positions in research in many fields of science and engineering; they have done correspondingly well in the selection and advanced training of scientists and engineers. However, the educational establishment as a whole and the universities in particular are faced with tremendous new challenges in developing the broad range of human talent and educational methods necessary to support and manage a modern technological economy.

In addition, the needs for more individualized education for a larger fraction of our population over a greater portion of the human life-span call for major innovation and amplification to cope with unprecedented needs. Whereas many service functions such as banking, insurance, communication, and travel have been radically affected by the incorporation of modern technology, educational institutions have, for the most part, been slow to incorporate change, in the form of either technological, administrative, or instructional modifications. Our institutions of higher education are at the forefront of both research and development in such fields as agriculture and computer technology. They have contributed less in their own field of education to the encouragement of innovation or the incorporation of modern technology.

A similar situation characterizes the provision and delivery of health services. Although advances in health science have increased life expectancy, existing methods for the provision of care to the poor, the aged, and the institutionalized remain inadequate.

The Committee is well aware, of course, that programs of R&D in both education and public health are presently under way. In view of the burgeoning needs of a growing population in a rapidly changing environment, however, we must recognize both needs and demands, not only in areas of urban and rural poverty, but in all parts of the country. They call for major increases in graduate education and research, not only to train badly needed additional professional manpower in these fields, but also to bring innovation and new technology into the delivery of the necessary services.

The Committee is also aware of the fact that whatever advances are made in education and public health will redound to the benefit of advanced as well as backward regions. Indeed, it is likely that despite any efforts that may be made to orient such programs toward the backward regions, more advanced regions will be alert to the potential in any new developments and may be even more responsive to them. Attempting, therefore, to improve the backward areas by such new techniques is likely to require concentrated attention and special effort, directed at assisting them in reaping the benefits they so desperately need.

The needs in the areas of education and public health constitute urgent reasons and significant opportunities for the development of *distributed national programs* of research and development in these fields.

The Improved Utilization of Natural Resources—Enhancement of the Quality of the Physical Environment

Research and development have been among the principal forces in developing new approaches to the exploitation, replenishment, and utilization of natural resources. In these developments, institutions in all performing sectors have had a significant role. Industrial research and development have been responsible for new methods in oil exploration, modern coal mining, and the development of techniques for the exploitation of the huge taconite deposits in Minnesota. The Departments of the Interior and Agriculture sponsor such laboratories as those of the U. S. Bureau of Mines, regional agricultural centers, state geological surveys, and water-resource centers. Many of these are operated by or in cooperation with universities, and for many years have been engaged in R&D on the regional problems associated with agriculture, forestry, mining, etc. It is characteristic of the older areas of research that cooperative and mutually supportive relationships have been built up over the years between the private profit-oriented laboratories and those in government and in universitites.

Increasingly, the scale and character of *man-made* technological resources have made major changes in the economies of regions formerly dominated by the location of natural resources. As an example, the development of economically competitive nuclear-power plants will have major consequences for the future development of regions that formerly were dominated by considerations of proximity to coal, water, or mineral resources. This man-made resource has both promise and threat for the economies of various regions. Whichever it is, the consequences must be assessed and dealt with on a regional basis.

In a similar way, modern man-made developments have had a major effect on the physical environment of regions; many problems thus created, such as air or water pollution and traffic congestion, have assumed national proportions; it is unlikely that they can be solved without federal R&D programs, perhaps similar to those set up over the past century to deal with natural-resource problems.

That all performing sectors in the economy should contribute to the analysis and solution of such problems seems clearly indicated. Furthermore, virtually every major region of the country has problems of similar broad character, though with unique local dimensions.

The Delineation of Regional Problems and the Development of Plans for Their Solution

Among the significant technological innovations since World War II has been the development of systems analysis and systems approaches to complex problems. They were accompanied and stimulated by the establishment of institutions typified by the RAND Corporation and the Institute for Defense Analyses. While not restricted to this type of institution, there is a great need for expanding such activities in the solution of regional or "distributed" national problems. Examples of the types of problems that might be addressed are:

a. design of new urban centers
b. specific environmental problems
c. social problems endemic to a local area
d. design of specific new transportation systems
e. development of under-utilized resources

It would be desirable to broaden the application of existing techniques to forecast the impact on various regions of new technological developments and thus to provide alternatives for economically injured regions. Such studies have been made, for example, on the impact of the mechanization of the coal mines and the changes from steam to diesel in the railroads. The broad implementation of such studies would help to anticipate the effects of other national decisions or developments of regional consequence; for instance, decisions to lower import duties on goods where the domestic production is concentrated in a relatively few areas.

A critical limitation on the utilization of systems analyses in the solution of regional problems often is the absence of a specified client. As contrasted with the situation typified by the Department of Defense sponsoring a systems analysis of weapons cost-effectiveness, the usual regional problem does not have a specified agency charged with the task of delineating or solving the problem. Indeed, in most cases, the region is not identified with a specified political unit or governmental body. Hence, in the course of the application of new technological approaches, *it is essential to elicit a client-sponsor.* The nature of an able client-sponsor may vary, depending on the problem. The client-sponsor to solve a transportation problem may be quite different from that required to solve the problems of water resources. As discussed in detail in Chapter VI, the elicitation of a knowledgeable and able client-sponsor is at least as important as the availability of technological resources for the application of R&D. In the hands of a viable client-sponsor, a systems analysis may be a powerful beginning to the solution of a problem; in the absence of such a client, it may be a futile intellectual exercise.

Chapter V

Dimensions and Distribution of R&D

Total Magnitude of Effort

The character and distribution of research and development activity in the United States is difficult to describe or to explain in a brief survey. Although large volumes of data have been assembled on certain aspects, many features of the national distribution of R&D are not clearly perceived because of the great complexity of the objectives, sponsorship, and locational considerations involved. While a historical perspective sometimes helps to identify the forces that led to the creation of such complexes as those centered in Boston or Los Angeles, there are also many features of such developments that were fortuitous. Furthermore, the presentation of the distribution of R&D according to geographic boundaries often fails to portray certain key aspects of the nature of the R&D enterprise or the features of the supporting infrastructure of a community that are conducive to the development of such enterprise.

A brief review of some of the available data will indicate some of the patterns of the present composition and distribution of R&D. This should help to provide insights into the role that federal policies may have played in furthering either the concentration or dispersion of R&D activity. The analysis that follows may also indicate some of the constraints that are encountered in any attempt to alter federal R&D policies.

In 1965, total expenditures for R&D in the United States were $20.5 billion, of which about $14 billion was carried out in industry, approximately $3 billion in federal laboratories, and the remainder divided between universities and other non-profit institutions. Of these funds, the major source was the federal government, which contributed $13 billion. Industry received almost $8 billion; thus, the federal government supported somewhat more than half of all industrial R&D.

In terms of manpower, the magnitude of the national R&D effort in 1965 consisted of 504,000 full-time-equivalent R&D scientists and engineers. Of these, industry employed about 351,000, or 70 percent of the total; 69,000 were employed by the federal government; 55,000 in universities and colleges proper; and 28,500 in federal contract research centers and other non-profit institutions. Some over-all perspective is useful; the total number of R&D scientists represented less than one percent of the total labor force of 75 million in that year, while the total expenditures for R&D represented about three percent of the gross national product of $681 billion.

Perhaps as significant as the total magnitude of effort in R&D have been the rates of growth of effort or expenditures in recent years. These have varied between sectors and have shown a recent tendency to level off. However, in the period between 1945 and 1965, the rate of growth in manpower was much greater than in most other areas of national effort. For example, R&D manpower increased (over the period as a whole) at a rate in excess of seven percent a year, while the total civilian labor force grew at less than two percent a year. However, it is probably more meaningful to compare this rate of growth with that of the "professional and technical" category of the work force, of which the scientists and engineers constituted 16.5 percent of the total (in 1963). The scientist and engineer work force increased 91 percent from 1950 to 1963, compared with an 85 percent increase for the professional and technical category as a whole (140 percent for scientists, 75 percent for engineers). Thus the growth in scientific and technical manpower was part of a larger trend in which the proportion of professional personnel as a whole increased very rapidly in comparison with the total work force.

Between 1945 and 1965 R&D expenditures rose by almost 13 percent a year, while the gross national product increased by less than four percent a year (in real terms). During much of this period, federal funding of R&D grew at a substantially greater pace than did the industrial commitment. However, during the past five years, the privately funded industrial R&D has grown at a greater rate, while the rate of growth of federal funding has tended to level off, under pressures of congressional and administrative limitations on expenditures. Total federal obligations for R&D in the fiscal year 1968 were approximately $17 billion or about two percent of the gross national product.

Distribution by Function and Performer

The National Science Foundation categorizes R&D activities as basic research, applied research, or development. Basic research, which accounts for about one eighth of total R&D expenditures, comprises original investigations for the advancement of scientific knowledge that do not have specific commercial objectives. Applied research work, which receives almost one fourth of R&D funds, is defined as investigations that are directed to the discovery of new scientific knowledge and that do have specific commercial objectives with respect to products or processes. Developmental activities, which receive over three fifths of all R&D outlays, are technical activities concerned with translating research findings or other scientific knowledge into products or processes.

Research work is widely distributed between the public and private sectors and within each of them. Colleges and universities typically perform the largest share of basic research work in the United States, but less than half. Governmental and industrial laboratories also perform significant amounts of basic research, as do private research institutions. Industrial firms and government laboratories both carry on substantial applied-research programs. A smaller scale of activity is reported by educational institutions and other non-profit organizations.

In contrast, industrial firms do the great bulk of all development work, about three fourths in recent years. The remainder is accounted for mainly by government agencies and private non-profit research institutions. While government turns to industry for the bulk of its development work, it does fund sufficient development work in universities to lend a more development-oriented flavor to university research than it would have in the absence of government funding. It is noticeable that the use that universities make of their own funds for support for R&D is much more highly oriented toward basic research than are the funds that they receive from government. Undoubtedly many in the universities conceive of their principal R&D missions as being contributions to basic knowledge, and view any forces pushing them in the direction of a development orientation as weakening or undermining their fundamental missions.

Private support for R&D comes from a wide variety of sources, including business firms, philanthropic foundations, and individuals. The public support, in contrast, has been highly concentrated in recent years. Two federal agencies, the Department of Defense and the National Aeronautics and Space Administration, account for four fifths of the federal financing. Most of the remainder is spent by two other agencies, the Atomic Energy Commission and the Department of Health, Education, and Welfare.

Distribution of R&D by Industry

As indicated in Table 1, a sizable fraction of the federally sponsored R&D is carried on in three major industry groups that receive a major portion of their

R&D funds from the federal government: (1) aircraft and missiles, (2) electrical equipment and communications, and (3) scientific instruments. These industries, whose combined sales represent only 17 percent of the total of U. S. industry, perform 85 percent of the federally sponsored R&D. However, these three industries account for only 20 percent of the company-sponsored R&D.

In contrast, the rest of American industry, which received the remaining 15 percent of federally sponsored research and development, financed the bulk of company-sponsored R&D, spending on the average almost three dollars for each dollar received from federal sources. Some of the differences are undoubtedly associated with the maturity of the industry; other differences have to do with patterns of procurement in defense, space, and other areas.

Although the research-intensive industries play a far more than average role in technological advance and innovation, they afford job opportunities to only a small fraction of the industrial population. The three previously identified research-intensive industries employ 56 percent of the 350,000 scientists and engineers engaged in industrial R&D; however, they provide job opportunities to only 2.8 million, or about 16 percent, of the 17 million employees in manufacturing industries. That is, high-technology industry pro-

Table 1 Distribution of R&D by Industries (1965)

	Federal R&D Funds ($ millions)	Company R&D Funds ($ millions)	Scientists and Engineers per 1,000 Employees (thousands)	Total Employment (thousands)
Aircraft and Missiles	4,500	620	113	873
Electrical Equipment and Communications	1,978	1,189	53	1,676
Professional and Scientific Instruments	125	261	36	295
Chemicals and Allied Products	190	1,187	40	1,022
Transportation Equipment	326	913	20	1,244
Machinery	258	870	27	1,228
Primary Metals	8	209	5	1,074
Fabricated Metal Products	17	129	15	442
Other Manufacturing Industries	102	957	10	3,374
Non-Manufacturing Industries	255	103	10	936
Total, R&D-Performing Industries	7,759	6,438	30	12,164

Source: National Science Foundation.

vides job opportunities preferentially for the most technically skilled portion of the labor market. Relative to the aggregate number of job opportunities, this sector of industry makes a relatively small direct contribution to the total.

The interactions between these industries as related to technology and innovation can not be assessed from such tables, however. Many of the manufacturing processes in firms that are not R&D-intensive are greatly affected by technology (both hardware and software) developed in industries that perform major segments of federally sponsored and company-sponsored research. For example, the airline industry neither finances nor conducts large amounts of research and development. Yet the services it provides embody a large input of science and technology. The airlines, of course, rely on the aircraft and manufacturing companies for the R&D work on aircraft, and on manufacturers of computers, radars, and communications equipment for R&D relating to the management of reservations and air-traffic control. Similar relationships exist in the case of scientific instruments and electronic equipment, which are utilized by many manufacturing companies that themselves do comparatively little R&D. Thus, although technologically sophisticated products and services may represent a very small percentage of the value added in a given industry, they may be indispensable to productivity. Hence the percentage of the gross national product represented by sales of high-technology products may be a very misleading measure of true economic importance. Moreover, the products of high technology may indirectly create many new job opportunities in other industries.

The concentration of R&D activities in a relatively small number of organizations is noteworthy. This factor also will bear on the geographic analysis that follows. The greater part of research and development activity is carried out in institutions that employ 1,000 or more R&D scientists or engineers. About 80 percent of industrial R&D is carried out by the 100 largest firms, while over 90 percent of university research is carried out by the 100 largest universities. (50 percent is carried out by 24 universities.)

It is to be noted, however, that company concentration exceeds university concentration. The top four companies in R&D performance accounted for 21 percent of all R&D and 28 percent of all federal R&D in 1965. The leading nine companies accounted for about half of federal R&D, whereas a comparable fraction of federally supported academic R&D involves 25 universities.

The relation between R&D and firm size is susceptible to misinterpretation. When firms are ranked according to the size of their R&D expenditures, they give the appearance of a very high concentration of R&D performance in large firms. However, as shown by Comanor[59] and by Scherer,[60] if firms are also ranked according to net sales, it is found that R&D performance is proportional to net sales. The percentage of net sales invested in R&D may vary widely from industry to industry but this proportionality holds for almost all types of industry. This is true whether specified in terms of expenditures, number of patents, or number of technical employees. For example, the largest eight firms in sales accounted for 15.6 percent of sales, 14.6 percent of R&D employment, and 9.3 percent of patents. On the other hand, the first eight companies ranked in order of R&D performance accounted for 35 percent of R&D and only 11 percent of net sales. The statistical paradox arises because different industries spend widely differing percentages of net sales on R&D, and the science-intensive industry classifications tend to spend more on R&D. However, within a given classification, there appears to be no bias toward higher percentages of R&D for large firms.

Geographic Distribution of R&D

In recent years, probably more emphasis has been placed on the question of the geographic distribution of governmental R&D funds than on any other aspect of federal policies regarding R&D. Table 2 shows the regional distribution of R&D and related variables in 1965.

It is immediately apparent that the distribution indicates certain significant disparities. It has often been brought into public view that the states of California, New York, and Massachusetts, with a combined population of 22 percent of the national total, perform 46 percent of federally supported R&D. By contrast, the states of the Midwest (the East North Central, West North Central, and West South Central regions), with 38 percent of the population, carry out only 17 percent of the federally supported R&D.

A feature of geographic distribution of R&D not often emphasized is that company-sponsored R&D has a pattern of geographic distribution distinctly different from that which is federally sponsored. Thus the northeastern part of the country (including the New England, Middle Atlantic, and East North Central regions), which accounts for 29 percent of federal obligations, performed 72 percent of company-sponsored industrial R&D. In contrast, western regions (Pacific, Mountain, and West South Central) received 55 percent of the federal R&D contracts going to industry and accounted for only 16 percent of company-sponsored R&D.

The geographic distribution also shows significant differences between the categories of research and the performing sectors. As shown in Table 2, R&D funds in educational institutions are more uniformly distributed geographically than are federal obligations to industry (with the exception of New England). Much of the concentration of graduate research in Boston and New York is historical; this area provided a preponderance of graduate degrees prior to World War II, and the support of academic research is signifi-

Table 2 Geographic Distribution of R&D by Regions, 1965 (Percentage Relationships).

Region	Federal Sponsored Fiscal Year (1965)			Industrial Company-Sponsored	Scientists Employed (1964)	Population
	Total	Industrial	Academic			
New England	7	8	14	8	7	6
Middle Atlantic	16	17	20	31	22	19
East North Central	6	5	18	33	17	20
West North Central	3	3	6	4	6	8
South Atlantic	15	9	11	5	15	15
East South Central	4	4	3	1	4	7
West South Central	8	7	6	4	8	10
Mountain	7	5	4	1	5	4
Pacific	34	43	17	11	15	13
Total	100	100	100	100	100	100
Three Leading States						
Massachusetts	5	4	11	3	4	3
New York	9	11	13	13	11	9
California	32	41	13	10	12	10

Note: Detail may not add to totals shown due to rounding.
Source: National Science Foundation.

cantly related to the number of advanced degrees conferred. A very substantial diffusion in terms of geographic distribution has occurred since 1946. The large universities of the Midwest perform a substantial portion of the graduate research and grant a sizable and increasing fraction of the advanced degrees in the nation.

Another dimension of the geographic allocation of federal research and development funds is the extent to which the funds are received by the high-income or low-income areas. Such comparisons should not be pushed too far because, as discussed elsewhere in this report, the long-term impacts of R&D are not necessarily felt in the regions in which the work is done. Nevertheless, such comparisons can provide useful insights.

Table 3 arrays the eight regions of the United States, ranging from the Far West, with the highest per capita income, to the Southeast, with the lowest average income level. It can be seen that, in general, the high-income regions tend to receive shares of R&D contracts larger than their proportion of either population or income and that, conversely, the low-income regions tend to receive below-average shares. However, the patterns are not uniform. In the case of NASA programs, for example, the southeastern region received a larger share of these R&D funds than of the total personal income, and the Mideast a substantially smaller share.

An important feature of the geographic distribution of scientists and engi-

Table 3 Regional Distribution of Population, Income, and Federal Financing of Research and Development in Fiscal Year 1964

	Percentage Distribution				
			Federal Research and Development Obligations		
Region	Population	Personal Income	Defense	NASA	NSF
High Income	*34.0*	*39.4*	*65.5*	*61.2*	*44.9*
Far West	12.7	14.8	38.0	47.6	14.8
Mideast	21.3	24.6	27.5	13.6	30.1
Average Income	*36.1*	*37.5*	*19.3*	*13.4*	*38.2*
New England	5.8	6.5	7.2	1.9	13.0
Great Lakes	19.7	21.1	6.2	3.4	15.8
Plains	8.2	7.7	1.7	7.8	4.3
Rocky Mountains	2.4	2.2	4.2	0.3	5.1
Low Income	*29.9*	*23.1*	*15.2*	*25.4*	*16.9*
Southwest	8.1	6.8	7.9	6.6	10.1
Southeast	21.8	16.3	7.3	18.8	6.8
Grand Total	100.0	100.0	100.0	100.0	100.0

Source: National Science Foundation.

neers is that the R&D scientist works in an urban setting. It has been estimated that 25 percent of all scientists are employed in seven metropolitan areas—New York City, Washington, Los Angeles, San Francisco, Boston, Chicago, and Philadelphia. The manpower data available do not distinguish between scientists and engineers who work on R&D and the total grouping of scientists and engineers. A sizable majority of the engineering population (about 65 percent) is committed to professional tasks other than research or development. However, a survey[61] of 14 major metropolitan districts in the United States shows that these cities contain 26 percent of the total population, 37 percent of the scientists, and 41 percent of the engineers. But it should be noted that, while these cities contain 27 percent of the total population, they contain 38 percent of the *urban* population. In other words, scientists and engineers do not usually live on farms or in small towns; for example, while 50 percent of the general population of Massachusetts lives in the Boston area, 63 percent of the state's scientists and engineers live there. The Chicago area has 62 percent of Illinois' population, and 74 percent of the scientists and engineers.

It follows that, in sparsely populated states, there may be very few centers for research and development, partly because there are few centers of population. In the mountain states, which generally view themselves as "have nots" in this field, there are relatively few metropolitan areas; however, Denver and Salt Lake City carry out important shares of the nation's R&D.

If research and development tend generally to be located in metropolitan areas, this is particularly true for small R&D firms, especially those that have recently come into existence. While large corporate centers for research may be relatively self-contained (for example, General Electric, Boeing, and DuPont), the newly formed high-technology corporation derives great benefit from sharing services and business derived from location close to other high-technology industry. These considerations should be taken into account in any appraisal of the geographic distribution of R&D in the nation at large.

Chapter VI

Mechanisms for the Implementation of Regional or Distributed National Goals in R&D

The Nature and Support of Distributed Goals in R&D

The distributed national goals for R&D envisaged in this report are in large measure oriented toward the correction of major social and economic problems that have arisen or become intensified because of uneven progress toward economic affluence. Programs to attain these goals can not be established without a national consensus and commitment. For example, the recent establishment of new agencies of cabinet rank, in particular the Departments of Transportation and of Housing and Urban Development, reflects the national recognition of the need for broad government programs in these areas. In a number of areas, programs are already being supported by the national government, though many are restricted by limited funding.

In addressing such distributed or regional problems as transportation, air pollution, waste disposal, control and prevention of crime, what is typically needed is a combination of centrally directed research broadly oriented to the problems, and locally directed R&D that views the problems in terms of specific local constraints. This is a pattern adopted by the U.S. Department of Agriculture, in the form of the regional laboratories of the Department, and the many university and industrial laboratories in this field. A similar dual approach characterizes the industrial scene in which research in major corporations is carried out both in the central research laboratory and at the product divisions. If the research is all done locally, it tends to be limited in viewpoint or to lead to wasteful duplication; on the other hand, if it is all done centrally, it tends to become unresponsive to local and special needs. In the context of regional problems, the solution seems to lie in a set of institutions oriented toward problems common to many regions, in cooperation with a network of institutions that address themselves to the problems of a given region, utilizing the more generalized results and adapting them to specific and local requirements.

Even in the case of distributed national problems such as transportation or agriculture or education, there are both central national goals and distributed national goals in R&D. For example, one might list the following R&D objectives as common or central national goals in transportation:

Design or study of supersonic jet aircraft

Design of a system of air-traffic control

R&D on new methods for land-based high-speed transportation

At the same time, there are needs for R&D aimed at distributed national goals of the following variety:

Design of a high-speed land-based transportation system for the Northeast Corridor

Design of a mass-transit system for the San Francisco Bay metropolitan area

Research on the extension of the shipping season on the Great Lakes

Systems analyses of the effects of highway location on urban development in the Midwest

Similarly, in centrally oriented national R&D missions, such as the space program, which is largely oriented to the national goal of pre-eminence in space science and technology, there have emerged some programs that are addressed to distributed or regional goals. Thus, the use of satellites for communication or for weather prediction may provide solutions to regional problems in different parts of the country.

The Committee believes that there is a growing recognition of the need for R&D in problem areas of a broadly distributed national character; it seems evident that federal funds will of necessity be an important factor in the support of such programs.

How much federal funding should be committed to *distributed* as compared with *central* national goals in R&D? This is clearly one of the most interesting questions that emerges from this report. This Committee has not had the time or the staff to make an analysis of the present expenditure picture in these terms or to project quantitative recommendations for the future. We believe, however, that further studies based on this approach may provide a sounder rationale for federally sponsored R&D aimed at broad national objectives. Since most major programs may have both central and distributed goals, such an analysis would also provide a better basis for considering the geographic allocation or origin of financial support.

Although a substantial portion of the funds to support programs aimed at distributed goals should be provided by the federal government, we believe that funds should also be provided on some reasonable and equitable basis from local and state taxes. Whether a program calls for better schools, more adequate transportation to recreational areas, or the removal of pollution from lakes and streams, the constraints imposed by the local geographic and political environment should be taken into account. This can be done if local and state governments contribute funds and take part in the decision-making process. It is important, however, that the financial matching requirements not be so onerous as to reduce or eliminate the participation of the lower-income areas with smaller tax bases. This consideration can be taken into account through the inclusion of measures of tax effort and/or an equalization feature in the fomulas for distributing such federal grants-in-aid.

In addition to specific R&D programs aimed directly or indirectly at given problems, federal policies for investment in R&D should promote the general objectives of such national distributed goals as regional economic development, technology transfer, and innovation.

The Role of Government Policies in Encouraging Innovation and Technology Diffusion

Over the years, the federal government has taken measures to foster the development of regions and facilitate the transfer of technology in a variety of ways. Early in its history, Congress undertook a number of responsibilities for "internal improvements" designed to encourage the development of the nation's interior. Later, land grants to the railroads, the Homestead Act, the Timber and Stone Act, and a wide variety of other such legislation was aimed at placing as many resources as possible in the hands of as many settlers as possible in order to encourage immigration into areas that Congress deemed to be in need of development.

The Morrill Act of 1862, establishing the land-grant colleges, and the Hatch Act of 1887, establishing the support of agricultural experiment stations, combined the twin goals of education and practical support of agriculture through research. In recognition of the necessity for active agents for transferring the new knowledge and new technologies to the farmer, the Agricultural Extension Service was organized in 1914.

Numerous other federal science programs were born in the decades following the Morrill Act. The U.S. Geological Survey represented an attempt by the national government "to explore, define, and describe" the geological resources of the nation in the hope that the consequent knowledge would lead to more effective economic exploitation of those resources. In addition, such institutions as the National Institutes of Health, the Bureau of Commercial Fisheries, the U.S. Bureau of Mines, and the U.S. Forest Service operate other research programs of value to various regions of the nation.

Despite this long history, the scope of federal R&D support and interest in national science policy was relatively small until the advent of World War II. At that time, the national defense required an effort of such dimensions and of such technological sophistication that the federal government was called upon to set up a new management structure, largely made up of scientists, not only to staff the weapons laboratories but also to direct the national program in weapons development. Since World War II, the continued growth in the federal support of R&D has profoundly affected the national posture in science and technology, and, in turn, the national economy as a whole. As the technologies associated with the defense (and later the space) effort increased in complexity and sophistication, new techniques of management, including the so-called systems approach, have evolved; these agencies of the national government have assumed the responsibility not only to provide the funding of R&D but also to establish the objectives and, in many cases, to assume responsibility for over-all management of important programs. This kind of applied program, largely aimed at development of systems for mission-oriented agencies, makes up the major share of national expenditures for research and development today.

Along with the buildup in military-space and other applied R&D activities, there has been very rapid growth in the support of basic research, particularly in the physical and life sciences, by agencies such as the National Science Foundation and the National Institutes of Health, as well as the Atomic Energy Commission and the Department of Agriculture. Like the development programs aimed at specific national objectives in technological hardware or software, the programs of basic research in science have represented central national objectives to which the nation as a whole has been committed.

In recent years, there has been a growing recognition that there are other national objectives that can not be reached through the support of basic research alone or through contract research tailored solely to agency missions. As a result, the nation has assumed additional objectives, for example, institutional development and technology transfer. Thus, the National Science

Foundation and the National Institutes of Health have set up programs of institutional or block grants awarded on the basis of promise and potential to universities and medical schools, as well as programs to encourage the development of new centers of research competence. These have been accompanied by similar programs supported by the Department of Defense and the National Aeronautics and Space Administration.

A family of programs designed to facilitate the transfer of new technologies has been set up. One of these is the Technological Utilization Program of the National Aeronautics and Space Administration. Fee-paying, private firms may be provided technical information services based on their "interest profiles" from several regional centers established at universities in various regions of the country. The Atomic Energy Commission has initiated similar efforts. In addition to the above efforts, Congress has broadened the original responsibilities of the Department of Commerce for disseminating technical information to private business in several new programs designed to facilitate the transfer of technological and scientific information. The State Technical Services Act of 1965 makes grants to the states "to provide technical services so that industry can benefit from technology to the fullest extent." In some respects, it is modeled on the Agricultural Extension Service, since the program is intended to encourage interactions among qualified universities, industry, and state governments. Under this program, in which local leadership and resources are emphasized, the states have been required to establish five-year plans for developing technical service programs. Then, through a variety of mechanisms involving person-to-person contact, information services, and conferences, attempts are made to improve the flow of technological information to enterprises that can make use of it. For the most part, this was intended to help industrial concerns that were somewhat behind the forefront of modern technological advance.

The analogy to the Agricultural Extension Service has not, in practice, been particularly meaningful. In the first place, industry is relatively mobile and is often not uniquely tied to the economy of a given state; a corporation may locate or relocate plants in other states or regions. Second, the State Technical Services Act is not accompanied by a series of acts such as those in agriculture that have supported major research programs aimed at local agricultural problems. Often the university participants are engaged in basic science or in sophisticated technological research wholly unrelated to the problems of their potential clients, who by contrast are in industries that lag behind modern technological developments. To overcome this cultural and professional mismatch, universities engaged in the programs of the State Technical Services Act have had to contribute substantially from their own resources in order to be as successful as they have been. At their best, university projects in this program have combined the public service role with their research and educational efforts. New programs of research aimed at distributed national goals would contribute significantly to the strengthening of relevant research activities and in so doing would greatly enhance the quality of the public service.

While elements of all recent programs at the federal level and a number of programs at the state level have significant relevance to the effective diffusion of technology, many of them appear to be based on rather limited views of the nature of technological transfer. In particular, it is important to realize that most technological innovation and transfer involves individuals with an innovative and entrepreneurial spirit. In order to train or to encourage others in the development of such qualities, contact with individuals imbued with this spirit is a key factor.

In this connection, there should be national recognition of a need in higher graduate education to support technical activities that involve the processes of invention and innovation. The universities should be concerned with how science is put to use, and support both science and the art of using science. In engineering and in the social sciences, as in medicine, some of the best practitioners should devote themselves to applied problems rather than basic research. Programs in support of distributed goals in R&D should provide for this type of activity in our university system.

One of the important conclusions of this Committee is that the professional colleges of our universities have a continuing responsibility for carrying out research programs aimed at understanding and contributing to the solution of real problems posed by society. In recent years there has been a decided tendency in some professional schools to shift emphasis in the direction of more basic science or methodology; in some universities and disciplines the issue of faculty involvement in addressing the problems of society has developed strongly conflicting pressures.

It must be recognized that universities have not been overly successful in inplementing effective interdisciplinary work of a type called for in addressing major social and technological problems. Such efforts must of necessity cut across the traditional university departmental structure; but neither the organizational framework nor the system of rewards and promotion has been conducive to such activities. Nor has the system of research project grants to individual investigators encouraged cooperation between disciplines. While a strong case can be made that it is vitally necessary for the modern university to remedy what may be viewed as a deficiency in its structure or reward system, it should also be recognized that the departmental system has proved to be eminently successful in many fields of academic research, especially those in the basic sciences. It may be necessary to seek additional institutional means to cope with R&D needs in the public interest.

One approach is to establish cooperative programs between universities and mission-oriented not-for-profit institutions. Alvin Weinberg,[68,69] in a series of significant papers, has made a case for cooperative programs between universities and government-sponsored laboratories, in which the latter would assume responsibilities for programs aimed at the solution of major problems posed by society. Such cooperation is of great potential value to each of the participating institutions—particularly in providing mechanisms for the mobility of research personnel between basic and applied R&D programs. This exchange of talent is one of the strong arguments for locating such institutions in close proximity to each other.

There is a need for cooperation not only between universities and other not-for-profit institutions but also between institutions in the private and the public sector. A limited number of cooperative programs between universities and industrial corporations have recently been sponsored by the Advanced Research Projects Agency of the Department of Defense. Increasingly, the problems of our society call for the participation of private corporations along with public development corporations to serve as agents of innovation in the public sector.

The Buildup of Regional Strength in Research and Educational Institutions

In the pursuit of distributed goals in R&D, there are important roles for each of the categories of R&D performers: universities, not-for-profit institutions, government and industrial laboratories. A wide variety of R&D efforts is called for in addressing any of the major social and economic functions for which we seek invention and innovation, and competent institutions are needed in all regions of the nation.

The land-grant universities have indicated both the feasibility and the long-range value of a major program of distributed national goals in education. An enlarged program based on this model seems strongly indicated in the future; major improvements are needed in virtually every sector of education, from elementary and secondary schools through to higher education and continuing adult education. According to the projections of the U.S. Office of Education,[70] the number of graduate students would double by 1975 and triple by 1980 if opportunity were provided. Such a growth in higher education can not be accomplished merely by expanding the enrollments of the established prestigious universities. Some new universities will have to be formed or those that do not have traditions of research will have to develop them. This will make possible the establishment of centers of scientific and academic excellence in regions now lacking such facilities.

As indicated in Chapter III, a great concentration of resources is necessary to build a first-rate graduate program. Under the most optimistic circumstances it will not be possible for the nation to convert every institution of higher education into a major center for graduate research and education, nor is it likely that such a need would arise. Dr. Philip Handler, Chairman of the National Science Board, advocates that each state or group of states engage in planning activities to determine which of its institutions are to be the important graduate universities 10 years hence, thus obtaining the requisite quality.

In support of higher education, it would be a serious mistake to withdraw the project system of R&D funding, which has brought American science to the forefront of world science. Yet in the face of the urgent need for increased financial support, the current system, devised to purchase results and to support a relatively small group of students through fellowships, is wholly inadequate. In recent hearings on the "Miller" bill (H.R. 875) to establish a National Institutional Grants Program in support of higher education, virtually all witnesses supported the general concept of some type of federal institutional support according to a formula based in part on the number of students.

Certain needs, shared by all colleges and universities, might well be supported by a combination of institutional and project support. An example of such a need, shared by the well-established universities as well as the developing institutions, is access to computers for both research and education. Virtually all disciplines call for an introduction to and familiarity with the use and system logic of this new tool, which has the kind of revolutionary impact on every phase of life in this century that the steam engine had during the eighteenth century. A familiarity with this powerful tool may well be a requirement for most professions in the years to come. Within the next decade, all colleges or universities in this country should be in a position to provide ready access to a major computer facility for their students and faculties. It seems equally essential that access to major libraries also should be available to all college students. In the foreseeable future these two essential facilities (libraries and computers) may be electronically tied together in a single system like the telephone system or the national electrical power grid. A broad network of computer facilities providing a basic access for students in every part of the country is an example of a national distributed need in education. A continuing central national goal should be the advance of computer science and technology. Thus, the federal contribution to the support of computers in a given university might contain two components, one providing basic educational access to computers for all students and a second associated with the support of computer-centered research by the scientific and engineering staff.

In addition to support of educational facilities, there is a need for the support of graduate research in the developing institutions. This need might be met in conjunction with the need for research on problems of a regional nature, called for in every part of the nation. A network of newly established educational institutions might therefore be supported in their developing phases by institutional or block grants committed to the study of regional problems. The block grant is uniquely suited to work in the more applied areas, and it is also very well suited to the buildup of new universities. Applied work often calls for the cooperative effort of academic staff from different departments or disciplines as well as competent professional staff. The block grant to a qualified research administration is more likely to build cooperative efforts and to retain continuity of purpose than individual grants to each of the participants. This was demonstrated in the development of the agricultural experiment stations and the great state universities during the latter part of the nineteenth and the early twentieth century. Critical, of course, to any such venture is the selection of the educational and research leadership in the newly developing institutions.

As indicated previously, there are many R&D programs for which the university is not especially well suited. We have called attention to the need for other types of public institutions, both not-for-profit research centers and government laboratories, to provide the proper environment for scientific or technological activities committed to the solution of society's problems. Such laboratories have done outstanding work directed toward R&D objectives in both the military and civilian spheres. At the same time, one should not overlook the problems that most not-for-profit or government laboratories have had in retaining enthusiasm and personnel after their initial problems have been solved. Later in this chapter, we discuss some of the problems of as well as the need for R&D institutions committed to the solution of regional problems.

A discussion of the buildup of institutions supportive of a regional economy is not complete without reference to the role of industrial corporations and industrial research laboratories. Obviously, however, the location or buildup of such institutions follows a different logic and responds to initiatives different from those which derive support from government. It is implicit in the free enterprise system that the location of new industrial plants or laboratories responds to comparative advantages and to local initiative, as evidenced by economic, political, or environmental incentives. In addition, various entrepreneurial or trade associations may be utilized by a given region to attract new industrial or government installations on a case-by-case basis.

Programs aimed at distributed national goals may involve federal support of industrial development as well as investment by industry in both research and development on these problems, in which communities or regions as a whole are the ultimate customers. In certain areas, such as air transportation, a combination of federal subsidy, federal R&D investment, and private investment has led to a very powerful national posture. In other areas, such as ground transportation within metropolitan areas, new ventures are needed to solve increasingly difficult problems of traffic congestion, noise, or general inconvenience.

To bring a truly sophisticated approach to the joint participation of industry and government at all levels will call for special technological competence in those agencies of the federal government charged with achieving distributed goals; it will also call for new institutions by which local or regional competence is mobilized. Special not-for-profit organizations sponsored by major clients have served this purpose well in the case of some of the federal agencies, although industry has at times chafed under this arrangement.

Other arrangements for the joint participation of industry and the federal and local governments should be seriously considered. Successful approaches should be expected to vary significantly with the problems concerned; they depend, for example, on whether the objectives are better education, better housing, or the elimination of industrial wastes. Continuing interacting study groups involving technical experts from industry as well as from government and universities may provide a promising mechanism.

The Statement of Regional Problems and the Formulation of Regional Plans—State and Federal Efforts

Few major institutions in our nation today function without a broadly conceived set of long-range goals and a continually updated set of plans laid out to achieve them. On the other hand, the need for such plans at the state or regional level has been relatively slow in gaining recognition. In recent years, however, a number of states and a few metropolitan areas have attempted to improve their utilization of R&D in the formulation of plans for their economic development and in the solution of the social problems facing their citizens.

A recent study by Harvey Sapolsky[71] found that in 1967, 22 states and territorial governments and five major municipal governments had either established or were planning to establish science advisory units. New York formed the first such state unit in 1959, but most of the others have been established since 1963. Most of these bodies have been concerned initially with the political question of the distribution of federal R&D expenditures as well as the role of science in regional economic development.

A number of states have gone beyond the simple establishment of scientific advisory committees. New York, on the advice of its Advisory Council for the Advancement of Industrial Research and Development, established the "New York State Science and Technology Foundation." Pennsylvania has developed a similar "Science and Engineering Foundation," which is now making grants for contract research to institutions of proven expertise in subjects of direct relevance to the development of local economies. For example, it has awarded substantial support to the Franklin Institute in Philadelphia for research on estuarine pollution, a problem of substantial concern to industries in the Delaware Valley. Philadelphia, however, is also a major center of biological research and the state hopes over a period of time to enhance that city's pre-eminent position in that field through support of this kind.

The Commonwealth of Kentucky established Spindletop Research under a state charter and with substantial financial support. Spindletop carries out a considerable research program for Kentucky but can also provide contract research for other public institutions or private industry.

Mississippi, recognizing the difficulties that its governmental salary schedule would pose in recruiting high-caliber expertise, established the Mississippi Research and Development Center to provide much of the back-up planning and advice required by the state government.

In general, experience with these state programs has been somewhat disappointing; almost half of them have lapsed. In part, this stems from a lack of understanding by local and state political leaders of how to use scientific advice effectively. Part of it stems from the relatively small investment in R&D that individual states have thus far felt justified in committing. The two reasons are not unrelated. In addition, most scientists are reluctant to identify themselves with problems too narrow in scope or too rigidly defined. To circumvent these limitations, it has been suggested that the states could more profitably invest in R&D programs if they acted as regions rather than separately. Sapolsky, for example, observes that

> with the wider perspective and the larger base of a region, it is possible that local science communities will find more opportunities than they would have had to participate in the social and economic problems.[71]

The talent and experience called for in delineating regional problems and making plans are very diverse; they include competence in such fields as economics, urban planning, and various aspects of applied science as well as leadership in organizing this competence in effective teams of specialists. Since only a few institutions in the nation have proven capabilities along such lines, there is a need for building up the nation's R&D competence in addressing social and economic problems.

The Public Works and Economic Development Act constituted a major effort to provide mechanisms by which the federal government could provide aid to states that had not shared in the general development of the nation's economy. A number of features of the Act led to constructive interaction among states with common problems, and significant progress has been made in numerous areas. In particular, it placed the responsibility for the development of plans for economic recovery in the hands of federal-state regional commissions, an arrangement that is discussed in the next section.

It is fair to say at this time that there is a need for continuing review of mechanisms by which R&D may be brought to bear on the solution of local and regional problems. State governments have lagged far behind the trend in the federal government toward increasing utilization of modern technology and management science.

In support of state and regional objectives in these areas, innovation is called for both in institutions and in institutional relationships in order to benefit from modern developments in systems planning and management. On the one hand, we need competent technological institutions committed to solving regional or distributed problems; on the other hand, we need viable mechanisms by which the problems of a region may first be adequately stated and viable approaches to their solution be implemented.

Client-Sponsors for the Implementation of Regional Plans—Organization of Regions for the Improved Use of R&D

While competent, technologically sophisticated organizations are necessary to provide analyses and designs for the future, it is equally essential to elicit a knowledgeable client capable of implementing such plans. Indeed, in most cases, the client-sponsor must be clearly identified at the planning stage to permit stipulation of the various social, political, and technological conditions within which programs and solutions may plausibly be set forth.

Perhaps the most widely recognized and well-established client-sponsors that support R&D relating to regional problems are such federal government agencies as the Departments of Agriculture and the Interior and, more recently, the Departments of Transportation, Housing and Urban Development, and Health, Education, and Welfare.

Some client-sponsors have been provided by the combined efforts of groups of self-appointed farsighted private citizens and elected officials of vision and influence. The Allegheny Conference for Community Development, a group of influential community leaders, set forth a plan for enlightened reorientation of an entire metropolitan area. The so-called "Pittsburgh renaissance" was the result.

Another example of client-sponsor arrangement, which was developed in the State of California, is the School Construction System Development Project. This project, financed in its early stages by the Educational Facilities Laboratory of the Ford Foundation, made great contributions to the economic design and construction of new school facilities. The client-sponsor in this case was a group of school districts that collaborated in the use of the systems approach for the design and procurement of school buildings; the resulting structures were more attractive from both economic and educational viewpoints. In the absence of such a collective client-sponsor, it is highly unlikely that the systems analysis could have been effectively carried out or implemented.

The Port of New York Authority is another example of a client-sponsor, one which has initiated important operations research and analyses of transportation problems for the nation's largest metropolitan area.

State government agencies may also act in the role of client-sponsor for studies of local or regional problems. The Department of Business and Economic Development of the State of Illinois has sponsored a series of studies aimed at improving the long-range economic posture of the state.[72, 73] Such studies have been used in many states in efforts to attract new industries or to administer more effectively such complex state systems as those engaged in the provision of health or educational services.

In 1965, the State of California provided funds for studies of four major problem areas: information systems, transportation systems, control and prevention of crime, and management of waste disposal.[74-77] These systems analyses, carried out by major aerospace firms, were significant pioneering efforts in state funding of exploratory R&D, but not for their substantive results. It remains to be seen whether an adequately funded client-sponsor will emerge that is capable of continuing these studies and implementing the important recommendations. Even as wealthy a state as California is limited in the amount of funds available for certain programs, particularly in broad problem areas shared with other states.

In addition to limitations on state resources, there are many situations in which state lines may not be the proper boundaries for a viable approach to regional or local problems. In its report of July 1967, entitled *Modernizing State Government*, the Committee for Economic Development observed:

> The boundaries of many states coincide reasonably well with the economic and social interests of the citizens, containing resources and population adequate for economies of scale in state services. Even where population is small, geographic isolation may justify separate statehood—as in Alaska and Hawaii. But some states are severely handicapped in solving their most pressing problems because of awkward boundary locations. Metropolitan areas containing parts of two or more states are illustrative, as are river basin problems wherever major rivers form state boundary lines.
>
> Since no state, acting alone, can be expected to solve multi-state problems, there is an obvious need for active interstate cooperation. Occasional and slowly increasing use has been made of interstate compacts, which the United States Constitution has authorized since 1789. Still, the potential utility of this device is largely unrealized. Uniform state laws have been drafted on a number of important subjects, but comparatively few have been widely adopted.[78]

For some time, there has been a growing realization of the major limitations of local government units in dealing with problems that exceed their political or geographic boundaries, and several approaches have been used in attempts to circumvent some of these shortcomings. One approach is the formation of "special districts," in which a number of local units join in order to solve particular problems—such as water resources and transportation. This widely used and often successful approach has the advantage that one type of problem may call for a somewhat different geographic or political grouping from another; the "special district" is tailored to the problem. On the other hand, the proliferation of such districts itself causes problems; there are now over 20,000 such special authorities in the United States, each with specialized functions and jurisdictions. In referring to this situation, the Advisory Commission on Intergovernmental Relations observed in 1964,

> the establishment of special districts creates intergovernmental problems and is frequently an uneconomical means of providing services. Perhaps most important, their use has tended to distort the political processes through which the competing demands for the local revenue dollar are evaluated and balanced.[79]

Thus, while the special districts have proven to be of considerable utility in carrying out essential public functions, local governments often find such an approach more, rather than less, difficult because of the past proliferation of single-purpose authorities. Furthermore, since problems tend to change with time, "special districts" sometimes find themselves with obsolete mandates.

An alternative approach to the formation of joint government groupings is the "area development district." Such districts, set up under the provisions of the Public Works and Economic Development Act, have been formed in a number of states to aid in planning. The area development district is typically larger than a single county; its area is intended to tie together a "growth center" and the surrounding country it serves, including the rural periphery that is economically linked to the center. The development district is intended to be the area in which most of the residents work, shop, and spend much of their leisure time. This recognition of a need to relate the less-developed, rural districts and nearby metropolitan growth centers into governmental units is critical to the formulation of reasonable plans for economic development.

In two broad categories of regional problems, the participation by the federal government seems strongly indicated: (1) regional problems that encompass the territories of a number of contiguous states, and (2) regional problems that a number of states may have in common but for which the resources of a given state are inadequate. In either case, a mechanism is needed to assist the local or state government to formulate the problems in sufficiently broad terms, and to participate in and contribute to the solution of the problems.

One approach to providing such a mechanism for interstate and federal cooperation is provided by the Federal-State Regional Commission, which has been implemented under federal auspices, as set forth in the Public Works and Economic Development Act and the Appalachian Regional Development Act. It has federal and state co-chairmen, and is largely, but not completely, financed by federal funds. This approach, which has sought to take advantage of opportunities for joint action by the states, has been utilized in the establishment of six development regions. These have provided a basic framework in underdeveloped regions for establishing programs aimed at the provision of regional analyses and development.*

Unfortunately, the existing regional commissions were all too often formed on the basis of criteria related to underdevelopment (unemployment, level of income, availability of health facilities, etc.), so that the delineation of regions is made up much too exclusively of poverty-stricken areas with few prosperous growth centers. With the exception of New England, the interstate regions were not constituted in such a way as to optimize social and economic development. Thus, from the viewpoint of their geographic boundaries and focus, the present regional commissions also tend to be problem-centered—with little flexibility to consider the full range of opportunities for future development. In the shaping of such regions, care should be devoted to combining areas that share something other than economic stagnation. Indeed, it may well be in the national interest that some such mechanisms should be available to all regions, underdeveloped or not. History suggests that many of the underdeveloped regions of today were prosperous regions of yesterday.

This Committee has not attempted a detailed analysis of the accomplishments and deficiencies of the Federal-State Regional Commissions in Appalachia or elsewhere. Since such commissions have been in operation only since 1965, it would be premature at this time to make an over-all evaluation in view of insufficient evidence. We have listened to careful presentations of the objectives, and of some of the achievements and problems that have been encountered by the regional commissions. While significant contributions have already been made, we have also been made aware of deficiencies in the utilization of R&D and of problems stemming from inadequate inputs in the planning phase from industry, from not-for-profit institutions, and from

*An analogy has been made with the Marshall Plan, in which the European countries developed concerted plans for economic recovery after World War II. This is widely cited as an unusually successful form of aid program since the recipients themselves were responsible for most of the planning.

various local and state agencies. We have also been made aware of some of the significant problems and unintended consequences associated with unrelated federal grants-in-aid to local districts when there is no over-all plan. In the absence of a regional client-sponsor capable of relating the efforts of many federal and state agencies in a broad plan of action, isolated efforts may be fruitless or even counter-productive.

The Committee is cognizant of the continuing changes in the relationships between special districts or states, and recognizes the dangers of imposing fixed boundaries on changing situations, even at the regional level. For these reasons, and in the absence of a detailed evaluation of existing regions, we have refrained from making specific recommendations as to the organization of new regional commissions or the designation of geographic boundaries for new or modified regions. At the same time, we have an increased awareness of the need for viable mechanisms for fulfilling the role of client-sponsor in approaches to problems that many states face in common.

We believe that the Federal-State Regional Commissions constitute a major innovation and should be viewed as a significant experiment, not only to provide a client-sponsor for the solution of regional problems but also in other aspects of federal-state relationships. The commissions have provided a new approach to the utilization of federal funds from numerous agencies in a broadly conceived over-all course of action. This experiment in federal-state cooperation should receive continuing evaluation as a possible pattern for wider application in the future.

As a committee, we believe in a pluralistic approach to the creation of new client-sponsors. What is needed is a proper organization of regional interests and commitments, with aid from the federal government, particularly to sponsor long-range planning and the effective use of science and technology in the solution of regional problems.

Opportunities should be provided for competent, farsighted R&D institutions to anticipate or provide attractive solutions for regions that have not yet crystallized either the leadership or the initiative. A national program of support for R&D activities of this type would enhance the likelihood of finding solutions—for example, research and development aimed at industrial applications of a hitherto *uneconomic* natural resource.

Significant advances in the general area of regional development may come from individuals or groups, not by virtue of their formal responsibility, but rather on the basis of their commitments to private interests or to social advance in a region. A variety of approaches in this area will enhance the likelihood that the individual entrepreneur and visionary will find an opportunity to contribute to the solution of regional problems.

Exploratory Centers for Regional Economic Development

In the context of this report, regional economic development may be considered a distributed national objective similar to those in transportation, education, etc. In a corresponding way, R&D programs aimed at this distributed mission may best be carried out in two broad categories of R&D institutions—one oriented toward problems that many regions have in common, the other toward problems of separate regions.

In other sections of this report it is indicated that the national economic welfare is benefited by federal programs aimed at such central national R&D goals as eminence in important fields of science and advances in technological areas such as nuclear power, computers, and systems management. Similarly, the economic and social welfare of all regions may be benefited by distributed programs in education, health services, etc. In most cases, such activities may be described along functional lines, each serving the nation's economy.

If the above programs serve the economic and social needs that most regions have in common, what is the character of the R&D activities that are oriented to the economic welfare and responsive to the local conditions of a given region? Our Committee has attempted first to delineate three major functions that might be provided to encourage and systematize regional development, and then to consider the types of R&D institutions that might best serve them.

The first major locally oriented R&D function is a continuing comprehensive survey and exploration, both of regional problems and opportunities and of available capabilities and resources to meet them. Capabilities that can contribute to a region's economy reside in sources of venture and working capital, in human skills and talents, in entrepreneurial and business talent, and in natural resources. An intensive, continuing search for individuals with innovative talent and commitment is vital.

A second major R&D function involves social and technological invention, an organized effort to match potential solutions to implicitly or explicitly stated problems. The invention phase includes the development of new plans for regional development, the proposal of new ideas for industrial ventures, new uses for natural resources, new associations between existing industries, etc. As in other fields, invention in this context is characterized by considerable uncertainties and a high ratio of unsuccessful to successful ventures. The invention phase includes "reducing to practice" activities to demonstrate the feasibility or plausibility of a given approach. This might involve a new method for the utilization of oil-shale deposits, new systems for the disposal of mine wastes, or the analysis and evaluation of regional comparative advantages for the location of new industry.

The third major function is *innovation*, the transfer of new products, processes, or ways of doing things into widespread use in the region. This is the role of the technological or social entrepreneur; it involves the identification or establishment of specific industrial or governmental sponsors either to exploit new inventions or to utilize existing technology and know-how.

The Committee has devoted considerable time and discussion to possible means for providing the three regionally oriented functions listed above. It is persuaded that, in the long view, two major types of institutional frameworks are needed: on the one hand, there is a need for a broadly identified client-sponsor, which in effect defines the region to be served and sponsors the R&D activities. On the other hand, there is a need for R&D institutions committed to addressing the economic problems of the sponsoring region.

At the present time, there are relatively few organized regions that could aspire to the sponsorship of a regional laboratory for economic development; similarly, there are relatively few R&D centers to serve a given region. Although such not-for-profit centers as the Stanford Research Institute and the Midwest Research Institute were initially created to serve local industry and promote the regional economy, and they have continued to serve the local interests, there has been a strong tendency for such research institutes to "go national" (or international) and to seek clientele from all parts of the country. It is natural for the managements of such organizations to seek out the most innovative or responsive corporations as clients, or those able to benefit from R&D activities for which the not-for-profit institution has achieved great internal strength and national recognition. Thus, many of their clients are *not* found in home territory and, obviously, it is not in the interests of such free-wheeling institutes to restrict their activities to local clienteles. A national market for their product enhances both financial support and the buildup of special areas of competence.

How, then, is it possible to develop the necessary dual components of viable and knowledgeable client-sponsors and competent regionally oriented R&D institutions? Historically, there has been a chicken-and-egg aspect to the development of any such relationship. In many instances, a capable client-sponsoring agency comes first. Many government laboratories and such special not-for-profit institutes as RAND and IDA followed this pattern. In other cases, the R&D group is the initiator in establishing the client-sponsor. For example, the sponsorship of the Manhattan Project and, later, the National Science Foundation grew out of proposals of groups of scientists. This Committee recommends serious consideration of both approaches for the establishment of regionally oriented R&D institutions.

The Committee recommends the establishment or identification on a trial basis of a number of "Exploratory Centers for Regional Development." We believe that it is preferable that the initiative for establishing such organizations come from the local regions. This is most likely to occur where a major client-sponsor in the form of a regional commission or compact may already exist. In some regions, in which needs exist but a regional impetus has not yet been generated, one or two such Exploratory Centers might be set up on a pilot basis charged with identifying or encouraging the formation of viable regional client-sponsors.

Perhaps such laboratories should be created by redefining the missions of existing laboratories as technology and circumstances change. Such an approach would seem to be particularly appropriate to in-house government laboratories or contract laboratories supported by mission-oriented agencies, which, because of the accomplishment of their original missions, may have lost some of their original impetus. It is not uncommon for such organizations to become preoccupied with detailed implementation of programs, and for the leadership personnel to drift away, because the laboratory itself is confined to its original mission statement. If the sponsoring-agency mission is sufficiently broad, the more aggressive organizations often seek out new missions, adapting their preexisting capabilities by adding new capabilities as needed. They use funding from the supporting agency as the vehicle by which the organization is supported during the transition phase. Transitions managed in this way are in the best tradition of the American enterprise system, and merely parallel what is often seen in industry when a private firm finds that its original product line is becoming obsolescent, and makes a transition to new product lines.

While there are examples of in-house laboratories and government-contract laboratories that have made transitions to new missions successfully, there is reason to believe that the structure of laws, regulations, and funding arrangements are not generally conducive to such readjustments. There would seem to be some advantage in explicitly encouraging laboratories verging on mission-obsolescence to seek new missions, and particularly missions with regional orientations. In some cases there may be a need to obtain funding from other agencies; indeed, a transfer from one sponsoring agency or department to another may be called for. In the transition period, managements need to be given considerable discretion in expenditure of funds; lack of such discretion will seriously inhibit the adoption of a new mission.

Of course, the geographic pattern of high-quality laboratories needing mission reorientation does not necessarily coincide with the geographic pattern of need for regional laboratories. In some regions no such laboratories will exist, and R&D capabilities will necessarily have to be obtained by the formation of new institutions. Even in regions that do have such laboratories, the creation of wholly new laboratories may be a more effective approach than attempting to transform pre-existing R&D organizations.

The Committee refrains from specific recommendations as to the form and organization of such regional Exploratory Centers. We would recommend that a number of different alternatives be considered for the initial experiments. While one or two might be newly established, the first few Centers might also include (or be attached to) reoriented centers, such as one of the National Laboratories of the AEC, a free-standing not-for-profit institute, or a private corporation engaged in systems analyses and technology transfer. As indicated earlier in this chapter, there would be significant advantages in locating a newly established Center in proximity to a major university.

To carry out the functions set forth above, the Exploratory Centers would require a broad range of competence, including applied social and managerial science as well as applied physical and biological science.

The Committee recommends that an informed committee of national stature consider the design of organization that would avoid some of the obstacles that stand in the way of development of high-quality regional laboratories. Some of the necessary conditions and organizational needs that such Exploratory Centers would have to meet are:

attraction of a sufficient number of scientists and engineers to problems of less than national scope,

provision of stable, long-range support by regional and national sponsors,

maintenance of flexibility that allows regrouping within the laboratory and acceptance of new tasks,

transfer of both people and technology between the laboratory and the surrounding industrial complex,

encouragement of universities to involve graduate students in problems of this area,

cooperative activities with other R&D facilities in the region, and

a viable relationship to regional, state, and local government agencies and private organizations in the region.

The initial support for such laboratories would necessarily come from the federal government, particularly for the two functions of exploration and invention. However, continued support of such a laboratory after its buildup phase should depend in large measure on its success in contributing to the regional client-sponsors; an increasing share of costs, particularly in the implementation phase, would be borne by those in both the public and private sector who would directly benefit from a given innovation.

An essential feature of the mission of such an organization would be dedication to the problems of the given region. A key feature of its administration would be the participation of local agencies and individuals in establishing policy and direction. Performance would depend on broad competence, but would be assessed in terms of contributions to local regional development. The assessment of performance would be based on continuous review and evaluation of the various programs initiated by the Center; such evaluation would be made on the basis of reviews carried out by the Center itself as well as by the sponsoring agencies.

Since some of the projects initiated by a Center might involve programs requiring several years between initiation and completion—for example, a major urban experiment—the function of assessment and evaluation should be viewed as a significant part of the Center's operation.

In summary, the Exploratory Centers here envisaged should be viewed as both initiating and being part of a set of major experiments and experimental projects to which the federal government and the individual regions would jointly be committed. Such experiments should be initiated in order to gain new insights and to develop new approaches to the solution of the nation's major economic and social problems.

Summary of Findings

Chapter I. Major Objectives of Federal Policies for Research, Development, and Regional Economic Growth

We have found it important to distinguish between two major categories of national goals:

Central National Goals for R&D–such as leadership in the important fields of science, nuclear power, space exploration, and national defense–in which the program is national in focus, sponsorship, funding, and over-all direction.

Distributed National Goals for R&D–such as the development of human resources, the rebuilding of our cities, water resources, and regional environment for living–in which the programs are characterized by local determinants in the nature of the problems, in the approach to the solutions, and in their anticipated consequences.

These goals, while related in many areas, require distinctly different criteria for establishing priorities and means for implementation.

The Committee gave much attention to important social and economic constraints that increasingly complicate problems for which technological solutions have been traditionally sought; it also gave attention to the variety of ways in which technological advances may create as well as solve social problems. Hence, in its conception of R&D, the Committee found it necessary to include not only the natural sciences and engineering but also the social sciences and organizational and managerial technology.

The nation's federally supported research and development activities, while largely committed to central national missions, have played a significant role, together with industrially sponsored research and development, in raising many sectors of the national economy to positions of world leadership. In the process, some geographic regions have made greater progress than others, and have greatly benefited from the technological changes that have transformed our society. In the valid development of other programs to enable lagging areas to accelerate their progress, it is important to recognize the continued need for maintaining and improving a strong program of central national goals in R&D.

In broad terms, national policies for regional development should have two primary objectives:

To improve incomes and levels of living in regions by making it possible for the people in each region to increase their contributions to the national economy through development of the region's comparative advantages and full utilization of its manpower and other resources.

To assist in correcting major imbalances in the availability of social and economic opportunities among some parts of the nation and between some regions and the country as a whole.

However, each region of the country can not possibly become a duplicate in microcosm of the national economy. Diversity, migration, and change are all elements of growth and development.

The Committeee has not sought to recommend geographic boundaries or political organizations; however, it views the organization of multiple state and local governments into politically and economically viable units as useful to planning for economic development. For many problems, the precise location of the boundaries is not as important as that the jurisdictional boundaries of regionally oriented organizations or activities coincide. However, since most regional problems have different geographic patterns, it should not be expected that a given interstate, multi-purpose organization will be able to cope with all regional problems in its area.

Chapter II. Characteristics of Regional Growth—Regional Economic Implications Associated with the Location of R&D Institutions

If a region has appropriate cultural, political, governmental, and economic attributes, then R&D activities and institutions can contribute to human development within the region, to the region's comparative economic advantages, and to the quality of the total regional environment for living and growth. Indeed, R&D activities typically reinforce these attributes. Hence, it is not surprising that there is an association between the economic vitality of a region and the nature and magnitude of the R&D institutions located in it. However, a simple one-way causality does not describe this relationship: one could argue either that the R&D located within it has created a strong regional economy or that an economically vigorous region attracts and supports R&D institutions, or both. That is, there are strong mutually supportive relationships between a region's full development and the success of R&D activities within it.

The intensive incorporation of technology into manufacturing, agricultural, and extractive industries has brought significant changes in the nature of job opportunities and, hence, the experience and skills called for. Shifts of employment have taken place from one industry to another, from one geographic region to another and from one sector of the economy to another. Increasingly, access to economic opportunities is dependent in a crucial way on the development of human capabilities. Education and re-education for the future is mandatory for the good life of the individual, the community, and the region. In broad programs aimed at the development of human capabilities, this Committee feels that new efforts in research and development are called for. Education has come to be recognized as a continuing essential of life, not merely preparation for life.

The development of new R&D institutions or the improvement of existing ones typically requires long periods of time. Moreover, the important contributions of a given R&D institution either in terms of technological innovation, the development of human skills, or the improvement of the intellectual and cultural environment are achieved only after years of effort. Thus, it is important to consider resources devoted to the build-up of research and development institutions as an investment that may have long-term benefits to regional development.

Although the immediate economic effects of the location of an R&D institution on its surrounding community are often very important to the community, the indirect and long-range benefits in terms of the improvement of the social, political, and cultural environment are usually far more significant. The potential contribution of such an institution to the generation of new local industry is highly unpredictable; it is dependent on a number of factors, an important one of which is likely to be a community of other "high-technology" institutions in the immediate vicinity.

Chapter III. Characteristics of R&D—Incorporation of Science and Technology into the Economy

In the context of this report, it is very important to recognize the essential differences between research and development. While these terms embrace a broad set of overlapping activities, they are, generally speaking, committed to differing objectives, organized in different structures, and make different kinds of contributions to society. They entail differing emphases on the values of their end-products and the values of the processes through which end-products are achieved.

Because modern technology depends increasingly on the accumulated reservoir and conceptual structure of scientific knowledge, the collective efforts and products of the national community of science are of great value to the nation. However, it is hard to predict when a given contribution will be incorporated into useful products or whether a given increment of new knowledge will be useful to the particular institution that sponsored it. In addition to product values, research activities have important process values which contribute in a direct way to the mission of the sponsoring institution. The performance of research contributes directly to the educational mission of a university; in industrial or government laboratories, it helps to establish a desired intellectual environment and to provide access to the world's research effort.

Science and technology are incorporated into the economy through invention, innovation, and technology transfer. Technology transfer takes place in a variety of ways: among the most important mechanisms are (a) the marketing of capital equipment (including software), instruments, and new materials in which new technology is imbedded, (b) the movement of skilled personnel from one institution to another, from science into technology, or from one field of activity to another, and (c) the dissemination of information through personal contacts. The technology transfer process is critically dependent on people, their attitudes and motivation; it is social and economic in form and purpose.

To solve problems posed by society, invention and innovation are called for which meet increasingly complex social or political conditions as well as technological or economic constraints. Such innovations demand both social and technical ingenuity, typically combined in a single individual. To introduce new inventions into the economy, three types of innovators are needed: technical, financial, and civic entrepreneurs.

Chapter IV. R&D Activities Relevant to Regional Economic Development—Institutional Relationships

Major contributions associated with R&D activities may be categorized as follows:

Direct contributions to the economy through the development of new and improved products, processes, and techniques which can be manufactured, sold, or utilized by institutions in the region.

Contributions to the development of human capabilities and skills; basic and applied research play an important role in education and training.

Provision of new approaches to the extraction or improved utilization of natural resources located within the region. This includes enhancing the attractiveness of the regional environment.

The delineation of regional problems and the development of plans for their solution.

While the principal contribution to the invention of new products and processes that can be manufactured and sold in a region comes from industry, important contributions are made by each of the other categories of R&D institutions. Regional economic development can be aided by federal policies aimed at fostering innovation and the transfer of existing technology to new applications in both the public and the private sector.

Many of the regional problems of rural and urban America are associated with the failure of local and regional educational institutions to keep pace with the demands of a technologically based economy. National policies regarding R&D can affect this situation in two ways:

By providing effective support for graduate education and research, upon which adequate institutions and qualified personnel for higher education critically depend.

By supporting new programs of R&D leading to innovation and change in the educational process—formal and continuing—at all levels.

Technological developments have had increasing effects on the economic resources, on the physical environment, and on the amenities of life of communities formerly dominated by their geographic location and the availability of natural resources.

The development of sophisticated approaches in economic forecasting and systems analysis offers new opportunities for the delineation of regional problems and the development of plans for their solution.

Chapter V. Dimensions and Distribution of R&D

Total federal obligations for R&D in 1968 were approximately 17 billion dollars, or about two percent of the gross national product. The total number of R&D scientists and engineers represented less than one percent of the total labor force, but about sixteen percent of the professional and technical labor force.

About 70 percent of the total expenditure for R&D in the United States is in industry, approximately 15 percent in federal laboratories, and the remainder divided between universities and other non-profit institutions; the federal government presently supports somewhat more than half of all industrial R&D.

Eighty-five percent of the federally sponsored R&D is carried on in three industry groups that receive a major fraction of R&D funding from federal sources: aircraft and missiles, electrical equipment and communications, and scientific instrumentation. While they provide direct employment to only a relatively small fraction of the industrial population (about 16 percent) they contribute in important ways to new job opportunities and enhanced productivity in other industries. They play a significant role in innovation and technology transfer through the marketing of products and services.

The geographic distribution of company-sponsored R&D has a pattern distinctly different from that which is federally sponsored. The New England, Middle Atlantic, and East North Central regions, which together account for 29 percent of federal obligations for R&D, performed 72 percent of company-sponsored industrial R&D. In contrast, western regions received 55 percent of the federal R&D contracts going to industry and accounted for only 16 percent of company-sponsored R&D.

The greater part of research and development activity is carried out in institutions that employ 1,000 or more R&D scientists or engineers. About 50 percent of industrial R&D is performed by the nine largest organizations, a similar percentage of academic research is carried out by the 25 largest universities.

An important feature of the geographic distribution of scientists and engineers is that research and development tend generally to be located in metropolitan areas; this is particularly true for small R&D firms.

Chapter VI. Mechanisms for the Implementation of Regional or Distributed National Goals in R&D

In recent years, there has been a growing recognition that there are national objectives which can not be reached through R&D tailored solely to central national missions. As a result, the nation has assumed additional objectives, for example, institutional development grants for colleges and universities or programs for the encouragement of technology transfer.

The increasing support and utilization of R&D by the federal government has not been matched by a corresponding trend in state and local governments. Mechanisms are needed for encouraging both centrally directed research and locally oriented research on such problems as law enforcement, urban development, and waste disposal.

There should be national recognition of a need in higher graduate education to participate in technical activities which involve the processes of invention and innovation, i.e., how science is put to use. The universities should contribute both to science and to the art of using it.

There is a major need in virtually all regions of the country to enlarge and improve every sector of education from elementary and secondary schools through to higher education and continuing adult education. The need for support of graduate research in newly developing institutions might be met in conjunction with meeting the need for research on problems of a regional nature and supported in part by block grants committed to such studies.

While competent, technologically sophisticated organizations are necessary to provide analyses and designs for the future, it is equally essential to elicit knowledgeable client-sponsors capable of implementing such plans. In most cases, the client-sponsor must be clearly identified at the planning stage in order to stipulate the various social, political, and technological conditions that in turn specify which programs leading to solutions may plausibly be set forth.

Fragmentation of political responsibility frequently limits the effective incorporation of technological or social invention. Since state boundaries are not the proper regional delineations for the solution of many problems, serious consideration should be given to the formation of new regional compacts or federal-interstate commissions to act as client-sponsors for systems analyses, regional planning, and the implementation of plans.

R&D programs aimed at regional economic development viewed as a distributed national objective may best be carried out in two broad categories of R&D institutions–one oriented toward problems that many regions share in common, the other directed to the problems of separate regions. R&D institutions committed to the development of given regions as central institutional missions are needed to assure innovation in the form of valid long-range plans, better utilization of available resources, and the diffusion into widespread use in the regions of new technologies, organizational structures, and ways of doing things.

Recommendations

We set forth our recommendations in two sections: *National Policies for R&D* (I-IV) and *The Implementation of National Policies* (V-VIII).

Recommendations Concerning National Policies for R&D

To the extent possible, federal research and development programs should be organized in ways that are consistent with national objectives with respect to regional economic development. Because objectives of specific programs change and are stated in different ways from time to time, the policy recommendations which follow are cast within a general framework. The general objectives relating to regional economic development may be stated as:

The broadening of human-development opportunities in all regions of the country with the over-all objective of reducing major imbalances in the availability of social and economic opportunities.

Assuring for each region the opportunities to develop competence for dealing with social and economic problems susceptible of solution by science and technology.

Providing mechanisms by which a region may develop the initiative to utilize its resources, enhance its environment, and develop its production and service activities within the framework of national growth and development.

The Committee also recognized that there are two distinct sets of national objectives for R&D, in the context of which recommendations should be made:

Central National Goals for R&D—such as leadership in the important fields of science, nuclear power, space exploration, and national defense—in which the program is national in focus, sponsorship, and over-all direction.

Distributed National Goals for R&D—such as the development of human resources, the rebuilding of our cities, water resources, and regional environment for living—in which the programs are characterized by local determinants in the nature of the problems, in the approach to solutions, and in the anticipated consequences.

I. Federal policies for the support and conduct of R&D should include as major objectives the fostering of regional development, of the rapid diffusion of technology, and of innovation in the public and private sectors.

Since a rapid rate of technological innovation and technology diffusion is a key ingredient of economic development, federal agencies engaged in R&D activities should attempt to shape their policies with due attention to their possible economic implications, particularly including the transfer of technology from the immediate purposes of the agencies to other purposes and to the civilian economy.

Federal investment in R&D should take cognizance of the distinctions between what we have called *distributed national goals in R&D* and *central national goals in R&D.* Policies should be developed in such a way as to achieve the maximum possible beneficial contribution to each of these categories of national goals.

In order to foster the transfer of technology, large broad-activity federal research institutions should regard it as part of their function to encourage other federal agencies and missions and institutions in the private sector to use the technologies that they have developed.

Wherever feasible, the government should seek to stimulate technological innovation by means of generating commercial demand (for newly developed instruments, computers, technical services, etc.) rather than by direct support of R&D or the purchase of specifically defined R&D results.

The federal government should seek to stimulate innovation both by creating new industries in the private sector and by new approaches to problems in the public sector. Three types of innovators are needed: technological entrepreneurs, financial entrepreneurs, and civic entrepreneurs.

II. The federal government should delineate distributed national goals in R&D that will aid all regions of the nation to meet their needs in such areas as education, transportation, delivery of public health services, law enforcement and the administration of justice, clean water and air, and housing and urban development. The federal government should foster the establishment of programs for the implementation of these goals involving participation of both the public and the private sector and R&D institutions in all the performing categories.

Government at all levels (federal, regional, state, and local), as well as private industry and non-profit organizations, should be involved in the decision-making process and in providing funds in support of R&D aimed at the solution of these problems. In many areas, R&D is well supported, while in others, support is minimal. Greatly enlarged R&D programs will be called for in the course of the next decade.

Institutions providing such widely needed services as education, health, or law enforcement need increasing support and innovative approaches. These programs should be approached in pluralistic, decentralized ways, both geographically and institutionally, rather than through highly centralized direction and management.

Private enterprise should be stimulated in such areas as housing, natural resource development and exploitation, and transportation. Private corporations should be encouraged to re-examine and enlarge their R&D activities and services in the public interest. Public policies, such as in the area of taxation and regulation, may have to be reconsidered in order to promote greater participation of the private sector.

III. In the attainment of *central national goals in R&D*, it is essential to the national interest that the prime criteria for the granting of government funding be based on merit. While the agencies of the federal government should continue to select the most qualified and competent R&D performers, the federal policies for R&D investment should take cognizance of regional or distributed national goals.

In R&D activities relating to central national goals, particularly in the development of needed operational systems, the R&D programs should seek to achieve the maximum possible technological transfer and innovation consistent with the more immediate agency objectives.

1. Government R&D policy should avoid encouraging the development of completely self-contained capabilities within government-supported mission-oriented research institutions. These laboratories should be encouraged to develop and utilize independent suppliers who market their technical services and products to other users both within the government and elsewhere. Such a policy would assist in the diffusion of technology and thus contribute to regional development as well as to strengthening the private enterprise system.

2. Our nation should either lead or be at the forefront of research in most of the important fields of science. In the pursuit of this central national goal, the federal support of science should take account of other national goals, e.g., the education of future scientists, maintaining the over-all strength of the universities, and training engineers and other specialists needed in private industry.

3. Although prime contractors for critically needed products or materials should be selected without specific criteria as to the location of physical plant, the selection of alternative sources for such products or materials may appropriately take into account questions of regional distribution.

Policy for the location of newly established government laboratories or federally sponsored not-for-profit institutions should be coordinated with policies for regional economic development. That is, in the location of such government-sponsored facilities in a given region, sites should be selected where the cultural, environmental, and institutional attributes will enable the area to capitalize upon the new facilities in fostering further development. However, such site selection should not be made at the cost of significant degradation in the potential performance of the facility.

The location of an R&D facility or the support of R&D activities in the interests of the economy of a given region may sometimes entail an incremental cost over that for an installation at a more advantageous site. Whatever cost disadvantage is allowable should be recognized as a federal contribution to regional development. To the extent possible, the amount should be explicitly estimated and charged as a transfer from the economic development budget to the R&D funding organization.

IV. To provide for the maximum development of human capabilities, access to quality institutions of education should be available to citizens in all regions of the country. Since graduate research helps to provide superior educational opportunities at the university level as well as innovation at all levels of education, there should be a national commitment to the development and further improvement of centers of scientific and academic excellence in all major regions, particularly in those now deficient in such facilities.

In view of projected increases in national need and demand for graduate education, some new universities may be anticipated and a number of those which do not have traditions of research will be attempting to develop graduate-research capabilities. Both national and regional planning are needed to provide a rational basis for encouragement and support of those capabilities.

The federal government should support a distributed national program of research and development aimed at the improvement and the broadening of educational opportunities at all levels, including continuing adult education.

A national goal for R&D in education should include as one objective the development and introduction of new technology into the teaching process and into studies of the learning process.

There should be an expansion of research programs in the social and behavioral sciences aimed at a broadened understanding of learning processes, including research on the social and cultural factors underlying the ability to learn and to achieve.

Recommendations Regarding the Implementation of National Policies for R&D

V. R&D programs aimed at distributed national goals should be carried out in two categories of R&D institutions—one oriented toward problems that many regions share in common, the other directed to the problems of given regions. To encourage the technological and economic development of a given region, there is a need for competent R&D institutions that are committed, as a principal institutional mission, to the development of the region. A system of such institutions, here referred to as Exploratory Centers for Regional Development, should be seriously considered as a long-term objective; a small number should be set up on a pilot basis.

Some R&D institutions and programs should address regional problems for the nation as a whole, in areas like transportation, air pollution, and law enforcement, in which solutions are widely applicable to many regions. Coordination and joint sponsorship of programs at the national level should be carried out at the department or national agency level, e.g., Transportation, Housing and Urban Development, Commerce.

New programs aimed at distributed national goals should be initiated to increase the responsiveness of new and existing R&D institutions to the social needs and problems of the regions in which they are located.

1. The programs should foster an entrepreneurial spirit toward inventions leading to valid solutions of regional problems. They should recognize the social and economic problems associated with technological change and the constraints imposed on regional development by these factors.

2. University R&D addressed to regional development should be related to a national distributed goal for education.

As pilot experiments in the development of a national system of Exploratory Centers for Regional Development, a small number of such institutions should be established in regions in which needs for regionally oriented R&D exist and which are reasonably delineated in terms of geographic and political compatibility.

1. We believe that it is preferable that the initiative for establishing such an organization come from the specific region in which it is to be located. This is most likely where a major client-sponsor in the form of a regional commission or compact may already exist. In some regions in which regional organizations do not exist, Exploratory Centers should be set up on a pilot basis to work on problems of the region and to identify, or encourage the organization of, regional client-sponsors.

2. A number of alternative organizational structures should be considered for the initial Exploratory Centers. While one or two Centers might be newly established in regions for which existing R&D institutions may not be available or suitable, the first few Centers might also include (or be attached to) reoriented centers such as one of the National Laboratories of the Atomic Energy Commission, a free-standing not-for-profit corporation, a major university, or a private corporation.

3. The Regional Exploratory Centers should be broad-based institutions equipped to deal with complex systems problems and to carry out entrepreneurial functions; they should be of sufficient scientific and engineering status to perform and relate effectively at the forefront of national science and technology.

4. The functions of Exploratory Centers for Regional Development should include

(1) continuing survey and exploration of regional problems and resources;

(2) social and technological invention—the matching of potential solutions to regional problems, and the evaluation of alternative solutions including costs, values, and the time and resources required;

(3) innovation—the implementation and transfer of new ideas, new organizational structures, and new or existing technologies into widespread use in the region.

One of the major activities of an Exploratory Center would be a brokerage function: the identification of valid client-sponsors to implement a variety of new plans or ideas. Such client-sponsors, from both the private and the public sector, would in turn pose problems for research and development. In general, R&D institutions committed to regional objectives would share functions with comparable institutions in the same regions and elsewhere.

5. The financial support of the Regional Exploratory Centers should be shared by the federal government, and by public and private organizations in the regions.

VI. New programs aimed at the attainment of distributed national goals in R&D should be oriented to support and to benefit from the buildup of regional centers of research excellence in higher education. To provide orderly support for the development of an enlarged system of major institutions, a system of institutional grants from the federal government, which should be based in part on the number of students served, will be needed to supplement the existing systems of external support. In addition, there is a need for block or program grants for the development of selected fields or to solve special problems. These should be carefully administered to assure selectivity in funding to those programs which, in the course of their development, demonstrate greatest potential for superior performance in graduate research.

Research funding for new and developing educational institutions should be provided in large measure by national programs aimed at *distributed national goals* in R&D. These programs should also support R&D activities concerned with regional policy and problems carried out in established universities.

A system of block or program grants, especially needed for new and developing educational institutions, is also uniquely suited to the support of applied research programs concerned with regional problems. As demonstrated by the early development of the agricultural experiment stations, the block grant supervised by a qualified research administration is more likely to build co-operative efforts and to retain continuity of purpose than individual grants to each of the research participants. However, the continuation of regionally oriented block grants beyond an initial several-year period of buildup should be based in large measure on past performance and the provision of local contributions.

Although they should emphasize research efforts aimed at distributed goals in R&D, developing institutions should not be excluded from participation in R&D programs directed at central national goals. Such a restriction would be likely to work seriously against the development of high-quality graduate research in such institutions. However, the award of research grants directed at central goals would be made in competition with other institutions in the nation at large.

Because the large costs and the decades required make it completely impracticable for every existing college or university to develop into a major center of research and graduate education, each state or group of states should engage in planning activities to determine which local institutions should be supported to permit their development into graduate universities.

Current developments in the technologies of communications, information retrieval and transfer, and computer hardware and software should be encouraged and plans made to incorporate them into widespread use.

Access to modern computers and to libraries should be made available to all students, regardless of where they live and what schools they attend. A basic class of such service should be financed through a federal program of institutional grants, based on enrollment, to colleges and universities in all regions of the nation.

VII. The federal government should enlarge and improve its program of financial incentives to encourage regional planning activities, especially to incorporate R&D in the design of programs aimed at the solution of regional problems. Essential to these activities is the identification or establishment of knowledgeable and able client-sponsors.

The delineation of regional problems can be greatly aided by comprehensive surveys and systematic analyses carried out by capable and independent R&D

organizations; however, the political, economic, and social conditions can not be adequately set forth in the absence of client-sponsors charged with implementing proposed solutions.

The federal government should strengthen existing programs and seek to provide new mechanisms to encourage joint planning efforts involving participating private agencies, state or local government units, or governing boards and should provide advice and know-how based on experience gained elsewhere.

The initiative for proposing regional plans or the solution to regional problems should be sought in any appropriate sector of the public or private enterprise. Private corporations or businessmen, universities or university professors, and government agencies or their representatives should be encouraged by a system of matching grants to propose new approaches to the solution of regional problems.

VIII. In view of the continuing need to address regional problems that exceed the boundaries or jurisdiction of individual states, the federal government should re-examine and revise the delineation of congressionally designated underdeveloped regions and, recognizing that regional problems have different geographic structures, recommend mechanisms for organization of compacts or commissions to design and to sponsor regional programs.

The delineation of a geographic region should not be characterized solely by a common economic problem. The organization of regions and of regional programs should be based on viable economic and political relationships among states, metropolitan areas, smaller urban centers, and rural areas. Regional client-sponsors for planning and for the management of proposed development programs can be established by compacts among various governmental bodies.

Mechanisms should be provided within the federal government and at the regional level to assure that grant-in-aid programs from various agencies are mutually supportive and consistent with over-all objectives for regional development.

The Federal-State Regional Commissions, made possible under the Public Works and Economic Development Act and the Appalachian Regional Development Act, can provide a basic framework in the designated underdeveloped regions for more effective utilization of scientific and technical competence. Such Federal-State Commissions might be appropriate in other sections of the country for intergovernmental planning and coordination of joint programs, and not solely to promote economic development. The establishment of new regional commissions should take account of the experience of the earlier efforts, and need not necessarily be patterned exactly after these initial attempts.

Appendix A

Bibliography

Bibliographic entries are designated by an asterisk.

Introduction

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Appendix B

Contract Statement
Scope of Work

Article I—Scope of Work

A. The Contractor, as an independent contractor and not as an agent of the Government, shall provide all necessary qualified personnel, materials and services to conduct a study of the impact of science and engineering on regional development, and of the effect of Federal scientific and technical policies and prepare and submit reports on the results and findings.

B. The work to be performed hereunder shall be conducted as outlined in "A" above, and in accordance with the following:

1. A committee shall be appointed to organize a study on the impact of science and engineering on regional development. The goal of the study is to identify factors relating to the interaction of scientific and engineering research and regional development which are important in the consideration of Federal policies for the support of scientific and engineering research. The study shall be directed to, but not necessarily limited to the following:

a. How does science and engineering substantively affect regional development?

b. What characteristics determine regional science and engineering needs?

c. What are the functional requirements in science and engineering for effectively meeting regional needs?

d. What organizations are effective in developing regionally relevant science and engineering?

e. Do Federal science and engineering policies reflect "regional" science needs as distinct from "national" needs?

f. Can the needs of state and/or regions be met within existing Federal R&D programs?

g. What changes in Federal science and engineering research policies might stimulate regional development?

h. What Federal science and engineering programs would most effectively assist in the solution of regional problems?

2. These may or may not be proper questions, or in correct order for their consideration. As an initial step the study will seek to identify the problems and clarify the issues. Successive technical conferences will be held to refine further questions which are appropriate and to identify objectives and requirements that must be met in their treatment.

Close liaison with the Office of Regional Development Planning (ORDP) will be maintained during the course of the study for the beneficial exchange of ideas and to promote understanding of objectives. For example, there will be available a state-of-the-art review of current research on the impact of science and technology on regional development being conducted for ORDP by Midwest Research Institute. This survey will be available to the National Academy of Sciences study group as it proceeds and the interaction may suggest modifications that will be mutually beneficial.

Appendix C

Attendees at Conferences

February 3, March 9, May 12, and June 15, 1967

IRWIN H. BILLICK
Office of State Technical Services
Department of Commerce

JOHN ROBERT BORCHERT
Professor of Geography
University of Minnesota
Minneapolis, Minnesota

ERIC A. BOURDO
Michigan Technical University
Director of Ford Forestry Center
Houghton, Michigan

W. C. BRANDY
Office of State Technical Services
Department of Commerce

WILLIAM BRAYBROOK
The Franklin Institute Research Laboratories
Philadelphia, Pennsylvania

LEONARD BRONDER
Commerce Department
Michigan

SANDRA CALLAWAY
Economic Development Administration
Department of Commerce

WILLIAM M. CAPRON
Senior Staff Member
Economic Studies Division
The Brookings Institution
Washington, D. C.

W. N. CAREY, Jr., Executive Director
Highway Research Board
National Research Council

BENJAMIN CHINITZ
Professor of Economics
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CHESTER W. CLARK
Vice President for Research
Research Triangle Institute
Research Triangle Park, North Carolina

ALBERT CRENZ
The Franklin Institute Research Laboratories
Philadelphia, Pennsylvania

JOHN W. DAWSON
Chief Scientist
U.S. Army Research Office
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K. WARREN EASLEY
Vice President–Operations
Monsanto Research Corporation
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HENRY EINHORN
Economic Development Administration
Department of Commerce

ROBERT EISENMENGER
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Federal Reserve Bank of Boston
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WILLIAM ELLIS
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HENRY A. FAIRBANK
Professor and Chairman
Physics Department
Duke University
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FLOYD FISCHER, Director
Continuing Education
The Pennsylvania State University
University Park, Pennsylvania

LYLE C. FITCH, President
Institute of Public Administration
New York, New York

EUGENE P. FOLEY
Assistant Secretary of Commerce and
Director, Economic Development
Department of Commerce

JAMES FORD, Director
Economics Office
Ford Motor Company
Dearborn, Michigan

THOMAS S. FRANCIS
Federal Co-Chairman
Upper Great Lakes Regional Commission
Washington, D. C.

AARON GELLMAN
Vice President–Planning
North American Car Corporation
Chicago, Illinois

WELDON B. GIBSON
Managing Director
SRI-International
Stanford Research Institute
Menlo Park, California

PAUL J. GROGAN, Director
Office of State Technical Services
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EDWIN HAEFELE
Senior Staff Member
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M. F. HERSMAN
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Washington, D. C.

WILLIAM HOOPER
Office of Science and Technology
Washington, D. C.

SHIRLEY A. JOHNSON, Jr., Director
Denver Research Institute
University of Denver
Denver, Colorado

JAMES A. KENT, Associate Dean
College of Engineering
West Virginia University
Morgantown, West Virginia

ROBERT W. LARSON, Director
State Technical Services Program
New York State Department/
Department of Commerce
Albany, New York

CHARLES LEVEN
Department of Economics
Washington University
St. Louis, Missouri

MARY LOCKE
Office of State Technical Services
Department of Commerce

GEORGE LUCHAK
Professor of Systems Engineering
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FRED MANSBRIDGE
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WILLIAM G. POLLARD
Executive Director
Oak Ridge Associated Universities
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Vice President
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