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MASTER

A JOINT FEDERAL RESEARCH AND DEVELOPMENT PROCESS TO MEET STATE AND LOCAL NEEDS

DOE/CS/20251--T1 Pt. 1

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Part I AI01-79CS20251

Science and Technology and Political Decision Making

Part II

The Federal Response Mechanism

Part III

A Catalog of Federal Science and Technology Resources

Prepared for
National Science Foundation
Intergovernmental Programs

PROJECT PARTICIPANTS

Policy direction and advice for this project, entitled "The Development of Joint Federal Research and Development Processes Responding to State and Local Needs," has been provided by an Interagency Steering Group (IASG) comprised of representatives of the following federal departments and agencies:

Chairman:	National Science Foundation
Members:	Departments of Agriculture; Commerce; Energy; Health, Education and Welfare; Housing and Urban Development; Interior; Labor; and Transportation; and the following agencies: Community Services Administration; Environmental Protection Agency; Federal Emergency Management Agency; National Aeronautics and Space Administration; and the Office of Personnel Management.
Observers:	Office of Management and Budget; Intergovernmental Science, Engineering and Technology Advisory Panel.

A subcommittee of the Intergovernmental Science, Engineering and Technology Advisory Panel has functioned as a State and Local Government Advisory Panel (SALGAP), composed of the following representatives:

Thomas Anderson, Representative
State of Michigan

Julian M. Carroll, Governor
State of Kentucky

Picot Floyd, Former Manager
Hillsborough County, Florida

Francis Francois, Council Member
Prince Georges County, Maryland

Richard D. Lamm, Governor
State of Colorado

Dennis Lynch, Mayor
Pawtucket, Rhode Island

Carleton McMullin, City Manager
Little Rock, Arkansas

Gordon Voss, Representative
State of Minnesota

Principal Investigator: The Office of Harold F. Wise, Planning Consultant, 1200 18th Street, N. W., Washington, D. C. 20036 (202) 871-1422

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PART I

This Part of the handbook addresses the basic "how to do it"—how states and local governments can identify complex and cross-cutting issues and develop and manage scientific and technical resources in seeking policy solutions to such issues.

~~This part of the Handbook will deal with~~ the following subjects ~~matters~~ are discussed:

- Background Statement of the Issue;
- The Research/Decision-Making Process;
- Defining Problems and Identifying Research Components;
- Research and Decision-Making Strategies;
- How to Identify Existing Knowledge or Ongoing Research in the Area of Policy Concern; and
- Managing Multi-disciplinary Research. The fourteen agencies involved in this effort include: U.S. Departments of Energy, Agriculture, Transportation; Housing and Urban Development; Environmental Protection Agency, and National Science Foundation. (PSB)

The contents of this report reflect the views of the grantee, who is responsible for the facts and accuracy of the data presented herein, and do not necessarily reflect the official views or policies of the National Science Foundation, or other participating federal agencies, the members of the Interagency Steering Group or the State and Local Government Advisory Group.

This project has been financially supported by the following agencies (under NSF grant #ISP-78-17660 and contract #ISP-7917531):

National Science Foundation
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Department of Transportation
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INTRODUCTION

The use of federal research and development programs and federal scientific and technical resources by state and local governments in support of their policy-making needs is a relatively new phenomenon.

In fact, until very recently one did not hear of a science advisor in a governor's office, much less a technology agent in a mayor's or a city manager's office. Nevertheless, there is growing evidence that more and more state and local governments are going to need federal scientific assistance as they seek solutions to complex policy issues.

The facts and recent history surrounding these points are dealt with more completely in Part I of this Handbook.

With its three parts, this Handbook represents an attempt by the National Science Foundation, with the assistance of fourteen cooperating federal departments and agencies, to display the basic federal research and development and scientific and technical resources that are potentially useful to state and local governments.

Part I of the Handbook, Science and Technology and Political Decision Making, addresses the basic "how to do it"—how states and local governments can identify complex and cross-cutting issues and develop and manage scientific and technical resources in seeking policy solutions to such issues.

Part II of the Handbook is entitled The Federal Response Mechanism. It deals with how federal cooperating agencies will respond on an interagency basis to state and local needs.

Part III of the Handbook is a Catalog of Federal Research and Development Programs and Federal Scientific and Technical Resources—with Potential Utility to State and Local Government Policy Development Processes. The programs and resources listed in this catalog were nominated for inclusion by the cooperating federal agencies.

There is a very basic and important distinction to be made between the utilization of federal mission-oriented, categorical, operating or planning assistance programs and the utilization of federal R&D and S&T programs. State and local governments seek federal funds in operating areas of concern on an ongoing and recurring basis to achieve federal program objectives at the state and local levels.

On the other hand, federal R&D and S&T resources are used on a one-time basis where there is need for new knowledge or for the development of new applications of existing knowledge in new situations.

This Handbook seeks to point out the differences between continuing federal program support and the complexities involved in the application of federal scientific resources to complex state and local policy issues. Four principal differences are:

1. Multi-program or multi-agency: state and local R&D grant applications will tend to seek to solicit and integrate funds for cross-cutting or multi-disciplinary purposes from two or more programs within one department, or from among two or more agencies.

2. Multi-disciplinary: The research will tend to require integrating the efforts of a number of disciplines and may involve disciplines that frequently do not work together or that may be antagonistic toward each other.

3. Scientific and Technical Resources: There are additional complexities that arise from understanding the different views, research methods and bodies of literature of the various scientific fields. Further, there is an extension of complexity that derives from employing scientists directly in the definition and solution of problems in a political environment.

4. Research and Development: There are additional standards and criteria that separate acceptable research efforts from less rigorous problem-solving efforts. Not the least of these is the competence of the researchers performing the work.

The concern here is with applied, not basic, research and with problem-oriented, not academically focused, research. We deal here in that realm of government concern that lies between normal daily problem solving and basic research.

During the course of the development of a federal interagency response mechanism to meet state and local needs, the Interagency Steering Group considered five pilot project applications, which were submitted by a governor's office, a state legislature, two consortiums of local governments and a city.

The review process that was developed for the purposes of the pilot projects further illustrate the differences between ongoing federal program support and federally sponsored scientific and technical research. Pilot project applicants were instructed that, in part, proposals would be evaluated under the following criteria:

1. Is the complex, cross-cutting problem or issue significant, and is it clearly articulated?

2. Does the problem or issue pose important policy issues, and is there demonstrated in the application the process by which the project work would interface with state and local government policy makers? To put it another way, how will the proposed research and/or demonstration project be integrated into the state or local government's policy-making process?

3. Has the problem and issues statement been properly translated into research components?

4. Has the state or local government documented that it has checked the research components against other scientific research projects covering the same or similar areas of concern, either already accomplished or under way?

5. Are the scientific and technical resources proposed to undertake the work adequate and properly qualified?

6. How does the state or local government applicant intend to manage and control the scientific and technical resources assembled on a multi-disciplinary basis to undertake the work?

It is specifically to address, in an instructional and explanatory fashion, the issues posed by the questions noted above that this Handbook has been prepared. Its audience is principally intended to be state, areawide and local government officials who have to deal in policy matters containing significant scientific and technical components, as well as the scientists who will have to work with these officials, and the members of the federal scientific community who will fund and participate in these efforts. . . . all within the political decision-making contexts of the state and local governments involved.

The material presented within this Handbook has been compiled and written by the Office of Harold F. Wise. Assistance in gathering pertinent information was provided by persons within each of the participating federal departments and agencies. Their assistance is greatly appreciated. Personnel of the Office of Harold F. Wise who made significant contributions to the substantive nature of this Handbook are LaVerne Anthony Beck, Carol Freedman, Carolyn Price, Brandon Roberts, Deborah Sharp, Joan Towles and Jason Zeller. Special thanks go to Carolyn Price for the development and application of the Key Word Index and Program Finder and for organizing and preparing the Catalog material so that it would be in presentable form, and to Gail Holt, for her administrative support.

Consultant assistance on the project included:

Mary Schmidt Doebele, Cambridge, Massachusetts
Robert C. Einsweiler, Minneapolis, Minnesota
Dwight E. Jensen, McLean, Virginia
Dr. Sally McFarland, Sacramento, California
Randall Scott, Arlington, Virginia
Dr. Lowell Kent Smith, Redlands, California

Harold F. Wise

Harold F. Wise,
Planning Consultant and
Principal Investigator

PART I

SCIENCE AND TECHNOLOGY AND POLITICAL DECISION MAKING

A Handbook for Public Officials

Prepared By
Harold F. Wise
Dr. Lowell Kent Smith
Robert C. Einsweiler
Dwight E. Jensen

The Development of Joint Federal Research and
Development Processes Responding to State and Local Needs
(NSF Grant #ISP-78-17660)
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PART I

Science and Technology and Political Decision Making

This part of the Handbook will deal with the following subject matter:

- Background Statement of the Issue
- The Research/Decision-Making Process
- Defining Problems and Identifying Research Components
- Research and Decision-Making Strategies
- How to Identify Existing Knowledge or Ongoing Research in the Area of Policy Concern
- Managing Multi-disciplinary Research

Part I

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About the Authors and the Preparation of This Handbook

In one respect, the Handbook is a product of a multidisciplinary team effort. Fortunately, the team members knew and had worked with one another but they had not worked together as a single team. Further, they were geographically spread out. Wise and Jensen are from the Washington, D.C., metropolitan area. Einsweiler has his office in Minneapolis, Minnesota, while Smith is from Redlands, California.

The concept and general outline of the paper were set forth in the grant application to the National Science Foundation submitted by Harold F. Wise. The concept was honed and primary writing assignments were agreed to during several meetings held in Washington with all authors present. Wise was principally concerned with the writing of the Background Statement of the Issue and the Concluding Thoughts and Observations. Einsweiler dealt with the Research/Decision-Making Process, Defining Problems and Identifying Research Components, and Research and Decision Making Strategies. Smith developed the material on How to Identify Existing Knowledge or Ongoing Research In the Area of Policy Concern and Managing Multidisciplinary Research.

As draft material came in, it was exchanged, phone calls were made, revisions and new materials were developed. The final report was assembled and preliminarily edited by Wise. Jensen was the constant critic and editor.

Each of the team members made his own contribution from their own backgrounds, experience and training. The product, however, is joint in every respect, with all team members making contributions to all parts of the work. The experience was rewarding and enjoyable to all.

Briefly, the members of the writing team are:

Harold F. Wise

Planning Consultant, Washington, D.C. Consultant on physical, environmental and management planning and operations at all levels of government since 1948, including 28 state, governments. Formerly, member of graduate planning facilities at Yale University and the University of Pennsylvania.

Dr. Lowell Kent Smith

Associate Professor and Chairman of the Department of Biology at the University of Redlands, California. Received his Ph.D. in Marine Ecological Physiology from Stanford University. Has

done extensive research on the role of phosphorus in water pollution, problems of water analysis and more general studies on pollution in both fresh and salt water. Has also done work with computer modeling and simulation of ecological systems, especially aquatic ones.

Robert C. Einsweiler

Chairman of the Planning Program, Humphrey Institute of Public Affairs, University of Minnesota. Consultant to federal, state, areawide and local governments on planning, decision making and developing management systems. Formerly Director of Planning for the Metropolitan Council, Twin Cities Area, Minnesota, and President, American Institute of Planners.

Dwight E. Jensen

Communications and Public Affairs Consultant, McLean, Virginia. Formerly, Director of Public Affairs, National Governors' Association; State-Local Services Director, Advisory Commission on Intergovernmental Relations; Executive Assistant to the Governor of Iowa, (Harold E. Hughes); Assistant to two United States Senators (Hughes and Vance Hartke); Associate Editor, National Journal; and Reporter, The Des Moines Register.

The authors received advice and guidance from Mary Schmidt Doebele of the Massachusetts Institute of Technology; Randall W. Scott, Esquire, a public affairs attorney of Washington, D.C.; and Brandon G. Roberts, Jr. staff member of the Office of Harold F. Wise, A.I.P., Planning Consultant.

1. BACKGROUND STATEMENT OF THE ISSUE

Introduction

Science and technology (S&T) have profoundly affected and shaped today's life-style in America. The technological innovations of the past thirty years have significantly altered the way in which people work and live. The products of military and space-age research have radically modernized and computerized America's industrial and governmental work force.

In recent years, the emphasis in applied science and technology has shifted from military and industrial affairs to social and public management concerns. Science and technology have awakened to the problems of poverty, law enforcement, environmental degradation, transportation, housing and other areas, while still playing a major role in military and industrial undertakings.

This movement has, in part, been a response to the direction that some federal agencies have given research and development. However, this federal direction has not reflected a comprehensive shift in national policy, but is rather an independent movement by certain agencies.

A major potential component of any domestic research is its utility and application to the public sector. In the past, state and local government research needs have been only partially fulfilled by federal research and development programs through an unprogrammed filtering down of by-products from federally sponsored research efforts, the agenda for which were often determined by the program units of the same federal agency.

There are essentially two ways in which scientific and technological resources can be applied to state and local governments: through modernization and sophistication of the processes that deliver public services, and through improvements in the informational process and resources of state and local government so that science and technology can be conceptually and institutionally integrated into the policy-making process.

Research activities in the late 1960s and early 1970s focused on improving state and local governments' ability to deliver public services. This was a focus on improvements in the performance of existing programs under an array of existing policies. However, these research efforts did not provide solutions for the new and complex problems confronting state and local governments. It might be concluded that, during this time, research activities were not specifically oriented to public-sector needs.

Undoubtedly, both the scientific community and public policy makers shared, at that time, a lack of understanding as to the role of technology in addressing complex policy issues. Nor did they understand the ability of policy makers to shape their policy problems in a manner that would invite the scientific community to contribute to the development of policy approaches to new public needs.

Improvement in the State and Local Government Policy-Making Process and the Increase in Federal Transfer of Funds

In recent years, state and local governments have become aware of the importance of the policy-making process. In making policy decisions, they have realized that problems must be well defined, that alternatives must be understood, and that solutions must reflect the fiscal and political realities of an issue. To achieve these goals, state and local governments have had to modernize their institutional processes.

To a large degree, the state and local government modernization has been precipitated by activities of the federal government. The proliferation of federal programs and dollars made it virtually impossible for state and local officials to manage their affairs as they had in the past. The federal government increased its reliance upon state and local governments to carry out federal programs and policies by raising direct or indirect expenditures of federal transfer and grant funds from 10.9 billion dollars in 1965 to 68.0 billion dollars in 1977. The 1979 budget committed 82.1 billion dollars to the intergovernmental transfer of funds (i.e., from federal to state and local governments), while the 1980 budget estimates 82.9 billion (see Table 1). This magnitude of funds, coupled with increased federal reliance on state and local governments for implementation of federal programs, often resulted in the creation of new roles for state and local governments.

States have increasingly received federal mandates to implement specific federal programs. Table 2 is a list, drawn up by the National Conference of State Legislatures, of recent federal laws delegating implementation responsibilities to the states. The interrelated and interdependent effects of many of these programs have necessitated governmental reorganization.

Table 1

Historical Trend of Federal Grant-in-Aid Outlays to State and Local Governments

(Fiscal years, dollar amounts in millions)

Five-year Intervals	Total Grants
1950	$ 2,253
1955	3,207
1960	7,020
1965	10,904
1970	24,018
One-year Intervals	
1975	49,832
1976	59,094
1977	68,415
1978	77,889
1979 estimate	82,129
1980	82,937

Source: U.S. Office of Management and Budget, Special Analyses, Budget of the United States Government, Fiscal Year 1981 (Washington, D.C.: U.S. Government Printing Office, January 22, 1979)

Table 2

Examples of Federal Laws Delegating Implementation Responsibilities to the States

Title XIX of Social Security Act of 1935; (P.L. 271) as amended by P.L. 89-97, 7/30/65; P.L. 90-248, 1/2/68; P.L. 91-56, 8/9/69; P.L. 92-223, 12/28/71 (42 U.S.C. 1396, et seq.); P.L. 92-603, 10/30/72; P.L. 93-66, 7/9/73; P.L. 93-233, 12/31/73.

Federal Coal Mine Safety Act Amendments of 1965; (P.L. 89-376, 3/26/66, 80 Stat. 84).

Highway Safety Act of 1966; (P.L. 89-564, 80 Stat. 731) as amended.

Federal Metal and Nonmetallic Mine Safety Act of 1966; (P.L. 89-577, 9/16/66, 80 Stat. 772, 30 U.S.C. 721-740).

National Traffic and Motor Vehicle Safety Act of 1966; (P.L. 89-563, 80 Stat. 718) as amended by P.L. 89-670, 10/15/66; and P.L. 91-265, 5/22/70.

Omnibus Crime Control and Safe Street Act of 1968; (P.L. 90-351, 6/19/68, 82 Stat. 197) as amended.

Radiation Control for Health and Safety Act of 1968; (P.L. 90-602, 82 Stat. 1173, 42 U.S.C. 241 and 263).

Clean Air Act Amendments of 1970; (P.L. 91-604, 84 Stat. 1676) as amended by P.L. 95-190, 11/16/77, 91 Stat. 1399-1404 (42 U.S.C. 7410 et seq.).

Federal Railroad Safety Act of 1970; (P.L. 91-458, title II, 10/16/70, 84 Stat. 971-977, 45 U.S.C. 431-441) as amended.

Occupational Safety and Health Act of 1970; (P.L. 91-596, 12/29/70, 84 Stat. 1590) as amended.

Lead-Based Paint Poisoning Prevention Act of 1971; Title I (P.L. 91-695, 42 U.S.C. 4801) as amended by P.L. 93-151; and P.L. 94-317.

Coastal Zone Management Act of 1972; (P.L. 92-583, 10/27/72, 86 Stat. 1280, 16 U.S.C. 1451-1464).

Federal Environmental Pesticide Control Act of 1972; (P.L. 92-516, 86 Stat. 973) as amended.

Federal Water Pollution Control Act Amendments of 1972; (P.L. 92-500, 10/13/72, 86 Stat. 816, 33 U.S.C. 1251 et seq.).

Marine Mammal Protection Act of 1972; (P.L. 92-522, 10/21/72, 86 Stat. 1027, 16 U.S.C. 1361) as amended.

Marine Protection, Research and Sanctuaries Act of 1972; (P.L. 92-532, 10/23/72, 86 Stat. 1052, 16 U.S.C. 1431-1434, 33 U.S.C. 1401) as amended.

Noise Control Act of 1972; (P.L. 92-574, 86 Stat. 1234).

Emergency Medical Services Systems Act of 1973; (P.L. 93-154, 11/16/73, 87 Stat. 594-605).

Emergency Highway Energy Conservation Act of 1974; (P.L. 93-293, 87 Stat. 1046) as amended.

Juvenile Justice and Delinquency Prevention Act of 1974; (P.L. 93-415, 9/7/74, 88 Stat. 1109, 18 U.S.C. 4351-4353) as amended.

National Health Planning and Resources Development Act of 1974; (P.L. 93-641, 1/4/75, 88 Stat. 2225-2276, 42 U.S.C. 300).

National Mass Transportation Assistance Act of 1974; (P.L. 93-503, 11/26/74, 88 Stat. 1565).

Safe Drinking Water Act of 1974; (P.L. 93-523, 12/16/74, 88 Stat. 1660) as amended by P.L. 95-190, 11/16/77, 91 Stat. 1393, 1394.

Energy Policy and Conservation Act (EPCA) of 1975; (P.L. 94-163, 42 U.S.C. 6321-6326) as amended.

Energy Conservation and Production Act (EPCA) of 1976; (P.L. 94-385, 90 Sat. 1125) as amended.

Health Maintenance Organization Amendments of 1976; (P.L.94-460, 10/8/76, 90 Stat. 1945).

Resource Conservation and Recovery Act of 1976; (P.L. 94-580, 10/21/76, 90 Stat. 2795, 42 U.S.C. 6901).

National Surface Mining Control and Reclamation Act of 1977; (P.L. 95-87, 10/3/77, 91 Stat. 445, 30 U.S.C. 1201).

A significant aspect of both state and local government policy-making processes is their ability to acquire detailed and accurate information on issues or problems of concern. The number of complex issues which now face state and local government — either through necessity or by federal mandate (i.e., issues associated with the programs of Table 2)—is growing daily. Often these issues have scientific or technological components or implications that must be examined. The National Conference of State Legislatures has identified a list of issue areas whose S&T components confront the public sector. They include:

- Energy
- Natural Resources
- Land Use
- Economic Development and Growth Management
- Weather Modification
- Natural Hazards Management (drought, flood, earthquake, etc.)
- Privacy of Information
- Nuclear Wastes
- Environmental Management
- Medical and Health Care
- Public Finance
- Genetic Research
- Transportation

Since a large number of these issues are complex policy questions, the direct application of scientific and/or technical knowledge in the planning and policy formulation process is often necessary to arrive at appropriate decisions.

The Emergence of Cross-Cutting Issues

The term "cross cutting" has come to be used to describe the sorts of problems and issues that rise to the attention of a Governor's office, a state's legislative leadership, or a local government policy-making body because they cannot be dealt with routinely by specific departments or agencies. Quite often these issues cut across state (and federal) departmental areas of concern or affect more than one level of government, crossing traditional functional areas of responsibility. A cross-cutting issue usually requires an interdisciplinary analysis to sort out the relationship between causes and effects, and thus develop policy directions aimed at correcting or otherwise dealing with the cause of the problem.

A few examples can illustrate the nature of cross-cutting issues and problems, although this list is by no means meant to be all-inclusive.

- The poor, the elderly and minorities are concentrated more and more in older central cities. The cost of needed governmental services is higher in the central city than in the suburbs. There also has been a movement of tax-generating industrial development to the suburbs. These conditions are results of past public policy. The causes might be traced to a combination of factors — among them the development of the interstate highway program and easy housing credit for new subdivisions through Federal Housing Administration (FHA) and Veterans Administration (VA) programs, together with a desire on the part of young white families to escape busing within central-city school districts. Each of these actions resulted in functional responses which had a cumulative effect of creating the current complex situation. Public policy to ameliorate and cope with these problems will undoubtedly call for new initiatives in many areas, including: revitalization and improvement of the quality of life in the central city, metropolitan wide sharing of nonresidential tax revenues and adoption of policies resulting in a more compact urban development pattern, all on an intergovernmental basis. Health, education, manpower training, economic development, transportation and housing programs, as well as issues of public finance and the equating of revenue sources with the costs of needed public services, all are involved in this cross-cutting issue.

- The maintenance or restoration of good air quality represent a major problem that confronts many of our metropolitian areas. Solutions to this condition require the consideration of numerous issues, such as the economics of regulating industrial and vehicular pollutants and the effect of pollutants on health and agriculture, along with life-style considerations developed over generations. Such issues cover a broad spectrum of scientific and social science inquiry. Knowledgeable decisions require information from each of these areas as well as information about their cumulative impact on the overall problem.

- One state in the upper Midwest is in the process of converting from an agricultural economy, with its resultant settlement pattern, services and shipping requirements, to an economy that could very well be dominated by the energy industry — extraction, shipping and transportation, as well as generation and transmission. Questions have been raised regarding the impact of these shifts on the need for the delivery of all kinds of state services. Will the distribution of population be different? Is there a boomtown potential in the development of energy resources? What about health, welfare and educational needs; will they be different in a changed economy? What costs will change in individual state programs? How are these costs to be met? What will the tax base be? What needs will there be for local government services? While agriculture will remain as a major component in the state's economy, new economic activities will create the need for interdisciplinary, cross-cutting analysis and policy development both by the State Legislature and the Governor's office.

State Government Science and Technology Policy and Experience

The emergence of complex issues and problems that have significant scientific and technological components, and that are often cross-cutting and multidisciplinary in nature, is a phenomenon that confronts all state and local governments.

Policy statements by the National Governors' Association (NGA) and the National Conference of State Legislatures (NCSL) reflect the importance that these public interest groups place on the application of scientific and technological resources to the state policy-making process. NGA's 1978-79 policy statement on science and technology states in part:

> The federal government supports a multibillion-dollar research and development budget, which does not effectively meet state and local needs. Although many government-financed discoveries in science and technology have been adapted for practical use, this application has often been merely coincidental because federal research and development generally is not undertaken to address specific areas of concern as defined by state and local governments.
>
> If the general public is to derive maximum benefit from the civilian-oriented research and develop budget support at greater taxpayer expense, its investment must be reconsidered to embrace this broader range of scientific and technical problems.
>
> To achieve this greater return for state and local governments and their citizens, a stronger long-term relationship with the existing federal science and technology establishment must be forged.

In a resolution approved by its science and technology committee on August 3, 1977, NSCL took a similar stance:

> In order to improve the application of scientific and technological resources to the problems and issues confronting state governments, the National Conference of State Legislatures recommends:
>
> o That the federal government, working with the established intergovernmental bodies and associations representing state and local government policy makers, establish an agenda of critical issues and problems facing the states and their localities that can be used in designing federal research and development programs.
>
> o That each federal agency involved in research and development or regulatory program implementation establish effective programs to make the results of these efforts available to state government, and that an interagency focal point be established to provide information about these programs.
>
> It is further recommended that the several states:

- o Take action to apply science and technology resources to legislative policy-making process by participating in the State Science, Engineering, and Technology Program; and

- o Communicate their specific needs for scientific and technical assistance to the appropriate federal agencies and the NCSL Office of Science and Technology in order to facilitate the development of effective national research and development programs that meet state needs.

The position taken by these public interest groups is indicative of the S&T issues actually confronting state governments. The National Science Foundation (NSF), through its Division of Intergovernmental Science and Public Technology (ISPT), has been involved with states in this area for the past four or five years. Their involvement has resulted in the documentation of complex cross-cutting issues to state governments. Following are a few examples.

- o The issue of pesticides and their effective use and control confronts most agricultural states. In Minnesota, broad concern for environmental protection is the responsibility of the Environmental Quality Board, which is composed of seven major department heads and a representative of the Governor. The board, chaired by the state planning director, has established a task force on pesticides to explore the issue, describe the problem properly and list available alternatives. In this instance, much knowledge already exists and can be marshalled by the agencies involved. In addition, the issue has many dimensions — e.g., impact on crop mix, agricultural production levels, water pollution, farm income, public health — and must be looked at from many perspectives.

- o In Michigan, the recognition that certain complex issues cross traditional boundaries between departments has led the Governor to establish four cabinet councils — the Council on Urban Affairs, the Council on Environment and Natural Resources, the Council on Economic Development and the Council on Human Services. Each is composed of the directors of those departments whose jurisdiction crosses the topic area and of individual advisors selected by the Governor. The councils meet on a monthly basis to discuss major issues that cross departmental boundaries. Each department presents its assessment of the issue and its recommendation for state policy. The Governor who is thus provided with alternative views for determining his position.

- o Colorado has recently attempted to strengthen linkages between science and policy formulation. There have been four major attempts in the last five years to expand and strengthen the bridges linking information needs of the state government to the knowledge and research in the state. These have included the appointment of a Governor's Science Advisor and Council, the establishment of a Colorado Energy Research Institute, a proposal to initiate a Colorado Institute of Research on Public Problems, and the funding of a small Institute for Advanced Urban Studies. Each of these was designed to supplement the general capacity for ensuring that scientific knowledge is made available to those who need it — farmers, state legislators, executive officials and others.

- In 1975, NCSL identified the need to provide a Model Interstate Scientific and Technical Information Clearinghouse (MISTIC). Initially supported by the National Science Foundation, this clearinghouse also currently receives support from five federal agencies. MISTIC helps state legislatures deal with S&T-related issues by communicating their information needs to federal agencies and other sources of technical expertise located in universities, industry, other states and professional societies. As an information "brokerage," MISTIC has also kept the state legislatures aware of federal agency R&D activities related to their concerns, and in doing so, has supported intergovernmental S&T development as part of the state policy-making process.

The preceding is only an exemplary list of the types of activities and issues with which state governments have become involved in the area of science and technology. Suffice it to say, their involvement is growing. (ISPT reports that it has often been asked to fund projects to solve these complex cross-cutting issues because states have no identified process with which to approach a combined group of functional federal agencies.)

There is every reason to believe that the federal government, specifically the Executive Office of the President and Congress, has been recognizing this development.

New Federal Science and Technology Initiatives

President Jimmy Carter, in his first State of the Union address, emphasized this Nation's commitment to research and development. Mr. Carter said:

> The health of American science and technology and the creation of new knowledge is important to our economic well-being, to our national security, to our ability to help solve pressing national problems in such areas as energy, environment, health, natural resources. I am recommending a program of real growth of scientific research and other steps that will strengthen the Nation's research centers and encourage a new surge of technological innovation by American industry.

President Carter's willingness to increase funding for basic research, at a time when he insists on holding down federal spending, reflects the increased attention accorded science and technology in the past several years. Further, there has been congressional concern. Legislation entitled "The National Science and Technology Policy, Organization and Priorities Act of 1976" was passed reestablishing a scientific and technological advisory office within the Executive Office of the President. This advisory group is known as the Office of Science and Technology Policy (OSTP).

The purpose of this act was to establish a science and technology policy for the United States, to provide scientific and technological advice and assistance to the President, and to provide a comprehensive survey of ways and means for improving federal efforts in scientific research and information handling. A significant component of the act was the recognition given the intergovernmental nature of science and technology. The House-Senate conference committee report on the 1976 act expressed its unanimous conviction

> (1) of the soundness of the concept that state and local governments could profit from their own science advisory systems; (2) that such systems could be made more effective through appropriate liaison with the federal government; and (3) that greater cooperation and improved financial arrangements between the states and localities and the National Science Foundation are in order, including adequate additional financial support of programs designed to increase a state's capacity for wise application of science and technology to state and local needs.

As a part of this federal/state/local partnership, the act established an Intergovernmental Science, Engineering and Technology Advisory Panel (ISETAP) within OSTP to identify pressing state, regional and local problems which science and technology might resolve or ameliorate, and to develop recommendations on ways to enhance the transfer and utilization of research and development results to state and local governments.

In creating ISETAP, the Congress and the Executive Branch recognized the need to increase the involvement of state and local government in science and technology policy. It was felt that since state and local governments deliver most of the domestic services of the federal government and are actual or potential users for much of the federally supported domestic research, and since state and local governments can affect the extent of science and technology through their regulatory and taxing powers, efforts should be made to make federally supported research more applicable to the needs of state, regional and local governments and the citizens they serve.

Science and technology in an intergovernmental context includes the following, as identified by the ISETAP staff:

- Use of scientific and technical resources (modern technology products, software processes, research information, and scientific and technical personnel) in service delivery, policy development, and administrative and planning functions of state, regional and local governments;

- Knowledge gained from scientific inquiry that is applicable to problems faced by state, regional and local governments and knowledge gained from evaluations of science and technology applications, innovations or experimentations in these governments;

- Development of the capacity of state, regional and local government offices to apply scientific and technical resources, to handle issues with major technological or scientific components, and to utilize modern management methods; and
- Transfer of scientific and technical information from the research community to state, regional and local government officials in a form and manner to encourage its appropriate use.

Expanding State and Local Science and Technology Capabilities

Efforts to improve the intergovernmental nature of science and technology are being conducted by the Office of Science and Technology Policy, specifically ISETAP, and the National Science Foundation. ISETAP is primarily involved in setting federal research and development agendas that reflect the needs of state, regional and local governments. The National Science Foundation, through its intergovernmental programs, is concerned with improving the capacity of state and local governments to deal with scientific and technological issues. In both its core state and local programs and its more recently authorized State Science, Engineering and Technology (SSET) study grant program, NSF's assistance has been provided to support the study or development of an approach or mechanism that promotes the wise application of science, engineering and technology in meeting the needs of a state and/or its political subdivisions.

A growing awareness of the need for new knowledge and new technology on the part of state and local government has been emerging in recent years, largely because state and local governments (through their areawide organizations) have been required by the federal government to engage in a broad range of planning and policy making. This awareness has been stimulated particularly by certain programs of the Department of Housing and Urban Development (HUD), the Department of Commerce's Economic Development Administration (EDA), the Environmental Protection Agency (EPA) and the Department of Transportation (DOT). HUD's comprehensive planning assistance program (701), EDA's economic planning assistance program (302), EPA's water and air quality planning programs, and DOT's planning programs (mass transit, highway and air) together have raised a broad range of scientific and technological issues, in addition to encouraging management improvements and institutional changes. These programs have indeed paid for a great deal of applied research. Most importantly, however, they have created a climate within which the need for new knowledge to deal with new issues has more and more been recognized and accepted.

It can probably be said that NSF-sponsored state and local government S&T activities would not have appeared or received the acceptance that they have had not the climate for such a program been well established through the individual federal planning requirements and programs referred to above. NSF efforts and ISETAP are discussed in more detail below.

State-Level NSF Operations (SSET). NSF's State Science, Engineering and Technology (SSET) program has made study grants to forty-nine of the fifty Governors' offices and to forty-two state legislatures. These grants are for the purpose of assisting states in the evaluation of problem and policy areas involving science and technology and in the initial determination of the scientific and technological resources available to analyze the problems and to seek alternative solutions. Hence, these states in effect, are already on their way. They are potential users of the system outlined in this Handbook.

Local-Level NSF Operations. The local government component of NSF's Office of Intergovernmental Programs has established ten local innovation networks; some are multistate regional networks, others are statewide. These groups seek to apply new technologies to be applied to state and local issues. In addition, three national networks which vary according to the size of the user have been established. These networks open up and identify areas of concern where new knowledge or technology is needed. Their purpose is to translate the problems of local governments into an R&D agenda seeking federal response through research and funding. The three national networks are:

- Urban Consortium for Technology Initiatives. The Urban Consortium for Technology Initiatives is composed of the twenty-eight largest cities (over 500,000) and eight urban counties. The consortium provides a forum for representatives of the nation's major urban centers to meet regularly to define and set priorities for their R&D needs. The consortium seeks to increase cooperative urban-oriented research arrangements with federal agencies and the private sector, facilitate proof-of-concept testing, improve interjurisdictional information transfer, and stimulate market aggregation for science and technology applications.

- Urban Technology System (UTS). UTS has much the same objectives as the Urban Consortium. It is composed of twenty-seven local governments with populations between 50,000 and 500,000. UTS places technology agents in each member jurisdiction and involves back-up. R&D institutions whose resources can be called upon by the technology agents to assist the local governments in the system.

- Community Technology Initiatives Program (CTIP). CTIP also shares the objectives of the Urban Consortium. It is composed of twenty-seven municipalities and townships and three counties, each with a population under 50,000. The CTIP program focuses on the science and technology needs of smaller governments. It uses eight circuit-rider technology agents assigned from federal laboratories via the Intergovernmental Personnel Act.

The direct participants in these networks have developed a consciousness concerning the needs for the uses of research and development to improve and enhance the governance of their jurisdictions.

ISETAP. The Intergovernmental Science, Engineering and Technology Advisory Panel (ISETAP), and a group of Governors, legislators and locally elected and other public officials, has undertaken the assignment given to them by the Congress to establish a research and development agenda around the problems and issues facing state and local government. Initially some 600 problems were defined. These have been consolidated into ten groups of issues and ranked by priority. The American Academy for the Advancement of Science (AAAS) is holding workshops that include scientists and practitioners on these groups of issues to determine how science and technology can be applied to the development of solutions to the enunciated problems. The results of these AAAS workshops are being written up and are being made available to the federal scientific community and to state and local governments through their public interest organizations. In addition, the ISETAP staff is working to develop new approaches for marketing of these findings.

Conclusion

In short, a lot is going on. Presently, state and local governments are developing the capability of using scientific and technological resources to critique, assess and evaluate complex, cross-cutting problems, as well as to formulate alternative solutions. This capability is a new, evolving one. Three factors have contributed to its development.

- The modernization of state and local governments has increased their ability to infuse informational resources into the policy-making process.
- The implementation of federal programs with scientific and technical elements (see Table 2) by state governments has forced states and local governments to identify S&T components of an issue.
- The interest at the federal government level in applying R&D programs and S&T resources to meet public-sector needs has resulted in the

formulation of ISETAP within the Office of Science and Technology Policy and the implementation of NSF's intergovernmental program.

The increased ability of state and local governments to understand and use scientific and technological resources in their policy-making process will potentially precipitate new requests for federal assistance to examine issues. These requests will more than likely reflect the multidisciplinary nature of problems rather than the various functional concerns of mission agencies or the specialized nature of scientific discipline research. Thus, state and local governments can be expected to seek federal R&D assistance in areas in which they have had little previous involvement.

The R&D Catalog, which is Part III of this Handbook, lists forth-seven federal R&D programs from which states and local governments might solicit assistance. These programs reflect the functional concerns or specialized nature of functional mission agencies. Historically, the public sector has not utilized these programs to examine problems for several reasons:

- o The past inability to identify and understand the scientific and technology components of programs;
- o The inability of specific federal programs to solve cross-cutting problems and the exorbitant cost of packaging similar programs from different agencies; and
- o The lack of effective, standard mechanisms and procedures that respond to requests seeking to combine various programs into one grant package.

In addition to the federal R&D progams listed, the catalog also contains descriptions of an additional 173 federal programs that can provide scientific and technological support (resources) of potential aid to state and local governments in their search for new knowledge in complex and cross-cutting areas of policy concern.

With the increased S&T capability within state and local governments, it seems apparent that they will soon seek to utilize the federal R&D assistance for which they are eligible. In soliciting assistance that corresponds with their problems, they will need to combine existing programs into comprehensive packages. Unfortunately, federal R&D programs have not been structured to meet the cross-cutting problems of the public sector. There has not been an effective procedure at the federal level for R&D agencies to combine like programs into an interagency package. The development and institutionalization of such a procedure will greatly facilitate the grants management process through which state and local governments seek federal R&D program support.

The federal agencies which have the responsibility for bringing S&T resources to bear on issues they consider significant would benefit from a knowledge of, and a partnership with, the state and local governments which have a direct policy-level interest in utilizing S&T resources to resolve real-world issues. A means to achieve this partnership would be a process by which state and local governments could submit applications to the federal government for jointly funded R&D assistance packages.

Packaging federal R&D programs to meet identified complex issues at the state and local levels will mean that S&T will provide input into the political policy-making process to an extent not now possible. The solutions to cross-cutting issues often call for conflict resolution through the political process. Thus, a growing political awareness on the part of the scientific community and a developing awareness on the part of the political community of the application of S&T resources to policy resolution are inevitable products of the developments outlined in this background statement.

A process whereby state and local governments can solicit federal scientific and technological resources is set forth in Part II of this Handbook.

The remaining parts of Part I concern state and local capacity to utilize R&D resources. A research/decision-making process is outlined and then explained in order to assist state and local officials in applying R&D resources to meet public needs.

2. THE RESEARCH/DECISION-MAKING PROCESS

The research/decision-making process described in this part of the Handbook involves 11 steps, some of which can be eliminated in certain instances to achieve short cuts. The 11 steps are summarized below and are diagrammed in Figure 1, with more detailed discussion in subsequent chapters.

Eleven Steps

Step 1. Identify the Problem. For the purpose of this work it is assumeed that the elected officials in charge have identified the problem and presented it for solution. Thus, there is no extensive treatment of the literature for the task of problem identification.

Step 2. Define the Problem. Problem definition normally receives short shrift. Yet it is the key to any solution. The seeds of all potential solutions lie in how the problem is stated. Therefore, it is important to devote at least half of the available time and effort of a research project to a careful definition before proceeding to solutions. (See Chapter 3 for more detail.)

Problem definition can facilitate pulling together people from various disciplines and agencies because it provides a common point of focus. It is critical to identification and use of scientific and technological information because it breaks down the problem into manageable components. Finally, good problem definition supports a solid research proposal by defining the research agenda.

Step 3. Set Decision and Research Strategy. Political decision-making processes and scientific research processes are often quite different. This point is frequently overlooked in laying out a research agenda. It is crucial when the work involves scientific personnel who may be unfamiliar with the political process. To accommodate this fact, the strategy for arriving at a decision and conducting the research must be laid out in advance to establish the limits for inquiry, and to make clear to all involved how the information will be used. In this way the air can be cleared. (See Chapter 3 for more detail.)

Figure 1. to be entered at this point

Steps in the Research/Decision-Making Process

Step 4 Identify and Obtain Expert Assistance. The assistance may be available from state agency staff members, may be retained through consultants, or may emerge through outside experts brought in to work on a committee or task force. The identification of individuals may come through people already known to the staff, a science advisor, a standing committee, or a panel of scientists "on call" to the state or local government. Or names may be generated by accessing existing research and noting authors of relevant work. Technical expertise will be required to meet the quality research criteria of any federal agency and to solve the complex problems this program is designed to address. (See Chapter 5 for more detail.

Step 4B. Identify and Assess Existing Research. It is important reasons to become familiar with the body of existing research. One of the key screening criteria for research for grants is knowledge of existing research. Further, one may find solutions to the problem in existing research without need for further effort. And as mentioned above, authors of existing research may prove to be useful experts in solving the problem at hand. (See Chapter 5 for more detail.

Step 5. Evaluate Existing Research. The product of the search methods identified here or elsewhere constitutes raw data for problem solving. It is not a product usable by all. It is prepared by specialists and it normally requires interpretation and evaluation by trained people. It would be a mistake to presume that untrained people could read available research and apply it to a complex, highly technical problem not identical to the one described in the research. (See Chapter 5 for more detail.)

Step 6. Design Research Proposal. This step summarizes what has been learned in the previous steps and combines it with federal agency requirements to make a case for funds. It may involve a refinement of problem definition. It should involve a decision and research strategy and a means for managing the project and its experts.

Step 7. Process Research Proposal. This involves a new process proposed specifically for state and local government tapping of federal research and development funds. (See Part II of this Handbook.)

Step 8. Conduct Research. The main additional element to be added to the conduct of research using R&D funds is the management of the multidisciplinary team. (See Chapters 6 for more detail.) Other aspects are similar to research under standard categorical grants with which applicants are assumed to be familiar.

Step 9. Prepare Recommendations and Implementation Strategy. Strategies for implementing the research are needed because many of the issues involving science and technology information are highly emotional or the information itself may be inconclusive. Therefore, it is important in the process of preparing a recommendation to also prepare a strategy for the users of the information.

Step 10. Make Implementing Decisions. This is self-explanatory.

Step 11. Monitoring Decision Effects. This is the last step in the cycle. However, the monitoring may lead to a first step of subsequent cycles if new problems are engendered in implementing the solution of the previous problem or if the recommended actions fail to solve the problem as anticipated.

Comments on the Process

There are several important points about the diagram in Figure 1.

(1) It expresses only the relationships among the steps in the process. It does not express the relationships among the actors in the process.

(2) The diagram shows in heavy outline the 11-step path involved in the research/decision-making process. However, the same diagram could be used for a short-cut answer to a problem which would involve only steps 1, 2, 3, 4A, 9 and 10. That is, if funds or time were short, or solutions were obvious, the task might be solved merely by employing the advice of experts without engaging in further research or further search of data beyond that already known to the expert panel.

Alternatively, a slightly longer path would involve going through step 5 and then shunting to step 9. This course involves preparing recommendations based on existing research without engaging in new research.

Each of these three loops, the short loop that taps the heads of experts, the middle loop that taps existing research, and the longer loop that envisions conducting new place-specific research, are of a family. The basic process of solving a problem is similar. The only difference is the amount of new information, i.e., information not already known by the parties who must make a decision, that is brought to bear on the problem.

Finally, there may be a combination of short-range and long-range cycles. For example, in 1973 a fire retardant chemical containing PBB (polybrominated biphenyls) was accidentally mixed with cattle nutrients and subsequently shipped to several farms in Michigan. This mixture contaminated the animals that consumed it, and because of the properties of the chemical, became a long-term and widespread problem in the state. Because there was very little knowledge about the potential long-term effect of PBB on cattle and on humans consuming meat, milk and cheese containing it, and because there were conflicting recommendations regarding safe levels of PBB in food, the Governor called for a more intensive study of the problem.

A special advisory panel of six scientists from across the nation was convened and given a specific charge. This committee completed its work in two months and presented a report to the Governor with recommendations on the PBB limits and on directions for necessary future research, some of which is being pursued by appropriate research institutes in the states. PBB is still considered a statewide health problem requiring continual policy attention. Therefore, Michigan combined the short-range cycle (in which the state assembled a set of experts and took immediate action) with the longer-range cycle (in which a longer-term research agenda was designed to study the whole problem with more time and in more detail).

(3) An additional item not easy to illustrate is the fact that the problem definition may change following the identification of experts. There could be a first draft of the problem and a first proposed strategy leads to identifying experts, which in turn leads to a review and potential redefinition of the problem. Or the problem could be redefined after further information flows from the evaluation of existing research, or as a consequence of the additional detailing in the research proposal, or based on the results of the new research. Thus, it is not necessarily a once-through cycle. It may recycle at various points back through problem definition and on through succeeding steps.

(4) The diagram is drawn as a broken circle to portray more accurately the relation of short, quick studies to the longer one envisioned by this Handbook. Further, it was chosen to express the cyclical nature of research and problem solving, with new information leading to redefinition of the problem. The weakness of a circle diagram is that it is difficult to show the relationship between the time stream of the research and the parallel time stream of daily decisions by the elected official(s) for whom and with whom the research is done. Therefore, in Chapter 3 the steps are laid out in a straight line.

The following chapters address matters that should be considered proceeding through these steps.

3. DEFINING PROBLEMS AND IDENTIFYING RESEARCH COMPONENTS

There are many texts on problem-solving methods. We do not propose to cover the topic in such depth. We do propose to relate the task of problem solving to state and local public decision making, the decision making of elected and appointed officials.

Thus, the methods described will emphasize the capacity of government to act on a problem. They are appropriate for any of the three problem-solving strategies shown in Figure 1, i.e., the short-cut approach which relies on drawing existing knowledge from experts in the field, or going a step further to examine knowledge in print, or engaging in new research germane to the issue. The main concern of this chapter is the identification of those situations in which new research will be structured to deal specifically with a current defined problem.

Many problems become crises. They are so obvious that no special effort at identification is required. Crises may have to be addressed by the short-cut method or, at most, a search of the existing literature. If an item is truly a crisis, it is unlikely there will be time to obtain federal research and development funds. However, the Michigan crisis on PBBs did lead to a two-stage problem definition. The crisis was addressed in the first stage by the short-cut method, and interim action was taken. This was followed by a second trace through the process over a longer period and a new research undertaking. We will show through examples why it is important to try to foresee problems before they occur, and how shortness of time can directly affect the capacity to deal fundamentally with a problem. A crisis setting rapidly closes the options available for solving a problem.

This chapter is presented in four parts: a set of guidelines derived through experience, an illustration of a poor diagnosis, a suggested set of techniques for those without experience, and an application of the techniques to a current example — a powerline problem. Experienced problem solvers may skip to the following section at whatever point the presentation is overly familiar.

Guidelines for Defining the Problem

1. Be Rigorous in Problem Solving. The need for rigor applies to all three of the approaches illustrated in Figure 1. Rigor does not mean exhaustive effort; it does mean precision of logic and accuracy of analysis. By using a rigorous method, those engaged

in the analysis will learn much more about the problem and the appropriate way to frame it. For strategies involving evaluation of existing literature or a new research proposal, problem-solving methods of the type shown facilitate breaking the work into researchable components. These can be used in the literature search, in the grant application, or in identifying scientific experts to participate in problem solution. A third reason for rigor, if federal funds are to be requested, is that it is an essential precondition to receipt of funds for critical research.

2. Allocate Enough Time. Particularly if pressure is high for response to a problem, there is a great tendency to frame the matter quickly and jump to solutions. This is a mistake. As the philosophers long ago demonstrated and as operations researchers have more recently confirmed, proper framing of a problem is crucial to solution. How the problem is stated limits the solutions that flow from it. That is to say, the framing of the problem will separate solutions that are within definition from solutions that will be excluded. Particularly in complex, cross-cutting issues, it is important to spend time on problem statements because bias can creep in so easily. It may occur because the analyst is so near to the problem. Or it may derive inadvertently from functional specialization, personal experience or any number of reasons.

Good research strategy suggests that at least half the time allocated to reaching a solution should be saved for defining the problem. Preliminary research may be required to identify potential causes of the problem before workable solutions can be identified. Jumping from intuitively derived causes to solutions may be wrong.

3. Keep an Open Mind; Be Alert to Bias. It is important in problem solving to keep an open mind and a holistic view of the problem. The effects of functional bias were alluded to earlier. More importantly, keeping a view of the larger context within which the problem exists facilitates the identification of other aspects of the problem that may be worthy of investigation. One should treat the problem as an object to be picked up, turned around and examined from all directions. As one works through from causal situations to potential solutions, additional aspects of the problem may become clear and merit a new line of investigation.

4. Address Causes not Symptoms. It is in the nature of public problems that governments normally are forced to treat symptoms rather than causes. Politics, costs and time available all tend to inhibit moving down the causal chain to more fundamental aspects of issues, as shown by the illustration below. This reinforces the point made earlier about crises. Late-hour actions must be quite proximate to the

current development situation. Turning to the example below, it is when the power line is being built that the people protest and the crises emerge. By then it is too late to back up to root causes, to look at alternate locations for the power plant, or to initiate programs to cut consumption that might have averted the need for the plant. The analysis should proceed down causal chains as far as possible, identify solution strategies at each level in the causal chain, and then choose to pursue strategies as close to the root cause as one may come.

5. Separate Causes From Solutions. It is important in the conduct of the work to continue down the causal chain from the problem toward the root cause without getting sidetracked into solutions or getting solutions mixed up with identification of further causes.

6. Set Limits. Only in theory is it possible to proceed with no limits in a problem-solving situation. Limits expressed in terms of concept, spatial or institutional aspects, time or resources must be part of the situational constraints of the problem setting and description. The closer the problem is to a crisis, the more those limits must be set. The problem-solving approach applies to steps 2, 6 and 8 of Figure 1. Insofar as possible, there should be no more limits than necessary in step 2, and they should increase as analysis moves to steps 6 and 8. When in doubt, include aspects for study, rather than excluding them, in step 2. In the early stages, maintain a free flow of ideas about the nature of the problem and solutions, tightening the flow as the work advances through later stages of the process.

7. Cut Off With Diminishing Returns. As the work proceeds, the question will arise as to when one has gone far enough. When can one stop working toward more fundamental causes and shift to examining solutions? There is a natural diminishing return that will set in where the solution is internal to the problem. It will occur as the breakdown becomes less and less significant as an issue. When the root of a problem is external to the situation, the diminishing return will occur at the point where the action required is beyond the influence of the agency engaged in proposing action. For example, when looking at why an automobile won't start (which has an internal solution), one can go down through the electrical system and the fuel system. Upon getting to the starter mechanism, if the solution to a starter motor problem is to replace the whole motor, it would be inappropriate to analyze where within the starter motor the problem may be. That is a point of diminishing return. On the other hand, in the example cited of the power line, it may be inappropriate to proceed causally to aspects of the problem beyond the point at which the examining agency can act. This

may limit action on the current problem to the line itself because the power plant is owned by a private firm and is located in another state near its fuel source — beyond control of the state described. This shows, however, that earlier study of the power line problem might have led one to discourage the power company from locating its plant in the adjacent state at the mine mouth.

These points will be illustrated and elaborated by the following two examples.

The Wrong Diagnosis: Some Lessons

This illustration is of an elderly man with a medical problem.

> [The Gentleman], who was in his late sixties, complained that late in the day he suffered first blurred vision and then headaches and dizzy spells. An optometrist told him that his headaches and dizzy spells stemmed from moderate deterioration of the eyes, which in turn was the result of old age. Stopping the diagnosis here, the optometrist prescribed bifocal eyeglasses to compensate for the change in vision.
>
> As a result of his difficulty in getting used to wearing his new bifocals, the gentleman tripped on a step and bruised his hip. To be certain that it was just a bruise, he visited a doctor and in the course of his examination mentioned his blurred vision and headaches. The doctor then checked his blood pressure, which proved to be too high, and cited this as the primary cause of the vision and headache problems. To put the doctor's diagnosis in our terms, he had compared the patient's actual condition to a desired state of health and saw the announced symptoms as the cause of the difference. He, unlike the optometrist, did not stop there, but asked, "What's causing the blurred vision and headaches?" The optometrist had assumed the basic cause was old age, but the doctor had gone one step further and had pinpointed high blood pressure as the immediate cause. He then asked, "If high blood pressure is causing the eye trouble, what's causing the high blood pressure?"
>
> Here, he made the same mistake as the optometrist, assuming old age to be the direct cause of the high blood pressure. As a result, he prescribed medication and change of diet to provide symptomatic relief for high blood pressure. He, in effect, like the optometrist, treated the symptom since he could not deal with what he felt to be the root cause — old age.
>
> Several months later, a routine visit to the dentist revealed that the doctor, like the optometrist, had failed by not pushing hard enough to correctly identifying all the intermediate causes of the problem. The dentist found that the doctor had missed an important link, a molar in which the nerve had died and decay had begun. The impurities introduced into the blood stream by the decaying tooth were, in fact, the direct cause of the high blood pressure, which in turn was the cause of the eye trouble and headaches and dizziness.*

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* Newman, Summer, and Warren, The Process of Management (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1967), pp. 323-4.

There are a number of lessons in this example.

1. One must continue an investigation after the identification of a first potential cause or, put another way, continue asking "But what is the cause of . . . ?" until one arrives at the root. While symptomatic treatment may provide relief, it is not likely to be enduring.

2. The old man's medical problem illustrates how the nature of the work with which one is familiar can establish a biased or limited vision or a set of functional blinders in attempts at problem solving. The new concept of holistic medicine is aimed at the very problem contained in this example. Holistic views in problem solving in the public sector are equally important, if not more so. There is a danger in these multidisciplinary programs of pursuing functionally defined paths rather than maintaining a larger view. The projects should be inter-disciplinary, synthesizing something larger than any discipline could by itself while in the first problem-shaping phase. For later production of solutions, narrower functional specialties may be pursued.

3. This example has just a single line of causality, whereas the typical project or problem will have multiple lines. Further, this example is in the physiological realm, which is the most concrete and determinative. Had the problem been a psychological one which resulted in stress and the symptoms that the optometrist and the doctor identified, the whole linkage might have been more difficult. Certainly the solution would have been more complicated. In fact, in testing for an answer, psychological potentials for creating a physiological effect would have been as important to look at as the ones identified. When we are talking about complex, cross-cutting issues, they will almost always have multiple causal chains.

4. The example also is simpler than many because the solution is within the system containing the symptoms and created by a problem within the system. On the other hand, public problems more commonly have solutions that are outside the system examined. In this case, for example, there may have been environmental pollutants in the workplace that would lead to the same phenomena of blurred vision and headaches for the same reason — the environmental pollutants worked their way through the lung system into the bloodstream with effects similar to the poisons from the tooth root. Solving this external problem, however, involves working causally in both the external realm and the internal. The analysis of headache and dizziness to the blood poisoning isolates the external contamination to be traced and removed. Treating anything on the person would only be symptomatic.

Techniques of Problem Definition

As mentioned at the outset, there are many books and many variants on the general method of problem solving. The following is presented for those who are not familiar with this general literature or who have not established problem-solving procedures in their offices. It is a simple, workable set of techniques well suited to public problems.

Problem definition involves three main tasks: (1) describe the situation, (2) identify environmental or situational constraints to action, and (3) examine for causes of the problem.

Describe the Situation. If the decision-making process is goal oriented or normative, this step will involve identifying what the current situation is, what one would like it to be, and the resultant gap between the two. If, on the other hand, the decision-making process is adaptive or remedial (which is more common), the question would be what is wrong with the existing situation, who is harmed, why do something? This would identify the conditions requiring attention but not the extent of attention that should be given.

The key question is, "Why are we or they concerned about this condition?" A politician may be concerned because citizens are concerned, as is the case in the illustration below. By successively addressing questions about concern — "Why?" — one pushes the problem to ever more fundamental concerns. This will be illustrated below.

Most decision making by elected officials is adaptive, remedial or ameliorative; most planning by professionals, particularly in societal programs, is normative and "needs" based. This is not a choice of right or wrong but of different approaches. This definition of the problem will establish the values that will serve to screen the various alternatives. How the problem is defined at this point will constrain subsequent actions. After proceeding through an examination of causes and of alternatives, there may be a return to this description in order to set the statement in a new frame.

Identify Environmental or Situational Constraints. Identify those societal attitudes or limitations of budget, manpower or other constraints that would prevent certain solutions to the problem. These constraints should not be used to generate creative ideas for problem solution in step 2 of the process in Figure 1, but they will play an increasingly important role in limiting choices as research is firmed up and carried out.

Examine for Cause of the Problem. It is important that the examination for causes continue until the root cause has been found. The key question, which was illustrated in the example of the old man and his medical problem, is "What is the cause of the condition?" As mentioned, this question can either lead down to an even smaller point within the system, or it can lead up to even larger but more basic and fundamental policy outside the system, as we will see in the illustration below.

The search for causality provides some limits or bounds to the problem because it screens out unacceptable solutions or relationships. The focus on concerns additionally bounds the problem through excepting answers that are workable but not of interest. Combined, the focus on causality and on concerns leads to a problem definition that incorporates a well-stated fact situation with the political reasons to respond. It is thus a problem defined in context for political action.

In pursuing these questions it may be necessary to pursue causality and concerns separately for substantive and process aspects of the problem, particularly decision-making process concerns. This, too, will be illustrated.

Illustrative Problem — Power Line Location

The problem statement which follows is drawn from an actual current problem. It has been simplified and altered in some respects to enhance the points illustrated.

The Situation and Concerns. The problem can be defined simply as it appears on the Governor's desk. Citizens and farmers are virtually at war with the power company regarding construction of a high-tension line across their farms. If we accept this statement as it is given from the Governor to his staff or his science advisor, how do we begin applying what has been identified above?

The immediate concern of personal safety has been taken care of by others assigned by the Governor. After discussion with involved parties — residents near the line, power company representatives, state agency personnel — the following concerns emerged. The residents expressed early concern about the radiation or electrical field that would be created by the line. Pressed for why they were concerned, they gave three main reasons. The most important related to personal health effects of exposure. Another was a safety concern related to operating farm equipment and irrigation sprinklers under the lines. And there was a belief that communications equipment —TV, radio, telephone — would be disrupted.

A second cluster of concerns came from the power company and some state agency personnel. These included energy availability and energy costs.

A third cluster focused on the decision-making process. The residents felt due process was lacking because the Environmental Quality Board did not look at an adequate set of alternatives. They also felt the use of eminent domain by the private power companies had been abused.

The fourth set derived from the above. Again the residents stated that their farms were adversely cut up by the straight-line routing, and farming operations were needlessly hindered as a result.

The real case has further complexities, but this should be enough for illustration. Each of these concerns and the fact situation of how the line came into being should be laid out in more detail. But this will suffice for the first pass.

At this point, it is clear that there are substantive and process concerns. Further, it is found that the benefits of the project accrue to customers elsewhere who do not have to live with the line, and that those living with the line receive no benefit from it.

Situational Constraints. The line is under construction. All required steps were taken in a legally correct manner. The power will be needed within two years. There may be other short-term alternatives to shunt power. Thus, while this line appears to be fact, other potential ones may be handled differently. A near-term action is required on this one. Therefore, a two or three-step strategy may be pursued. Funds are available for research if needed.

Cause of the Problem. The proximate cause of the problem, as stated, is the operation of the power line and its general location. The reason for the power line and its general location is that the point of consumption in the metropolitan population is separated from the location of the power plant. That is because there is unmet demand in the metro area and there is an available supply of fuel in an adjacent state. The power company, a private firm, packaged this supply/demand situation with a power line and a mine-mouth generating plant. The specific location of the line was chosen to reduce construction costs and time to a minimum. Why that fuel was used, and why a plant was built at mine mouth will be looked at as one of the alternative solutions to the problem. To press the unmet demand further would be to raise large-scale regional population issues beyond the reach of this state government. And to pursue the fuel site further would get into resource economics that are beyond the control of the state.

Figure 2. Illustration of Steps in Problem Definition to be inserted at this point

The process part of the problem can be stated as an inadequate look at alternatives. This is caused by the inability under law to review the energy agency determination of need and to review the exercise of eminent domain by a utility. These two should be expressed more fully before pursuing specific solutions.

The work to this point can and should be diagrammed in some fashion so the various pieces of data are graphically linked. Figure 2 is one example of the substantive part of the work.

Generating Alternative Solutions. This task, contrary to the earlier problem definition, should be undertaken in a more open brainstorming fashion so maximum creative insights can be captured. We begin with the present situation on this line, which is just under construction, because the Governor needs immediate action on it. If it were only a proposal, one would start with alternatives at the most fundamental level. At this level, the most proximate level to where we are, what options are there that could respond to the stated concerns? A change in routing for the part not completed may positively address a number of concerns, but it also may result in increased energy costs (an impact to be looked at later). Placing the line underground may be explored. So may acquisition of additional property rights, e.g., acquisition with resale to people who would be willing to live in these locations, acquisition and lease-back or a variety of modes other than the one employed, which was the acquisition of limited easement by condemnation. Compensation could also be extended to health/safety effects. For example, the state could take out paid-up health/accident policies on the residents. The state or the company could establish a health and environment monitoring system because one of the difficulties in this issue is that the data are inadequate. Those promoting the power line say that there are no data indicating adverse health effects from the electrical field, and the protestors note that there are no data to prove that there will be no health problem or that it is safe to live there with the anticipated level of exposure. In fact, the data are inconclusive. Therefore, another option would be to monitor health and the environment with a commitment to adjustment when acceptable thresholds are surpassed. Combinations may prove most workable. This list does not purport to be exhaustive.

Now let us assume that the line and the power plant have not been built, but that they are under consideration as a proposal. This takes us down to the next level of causality, the separation of the population from the power plant site. The fuel supply relating to the plant has been located, but the plant itself has not been built. What are the choices? The choice used is to transport the energy from the mine to the consumer by converting it to electricity. Another is to put the plant at the population end and to move the fuel supply via rail or pipeline. (In this particular instance, that was evaluated. The adverse effects from the trains hauling coal were considered more damaging environmentally than the adverse effects of the power line. However, the difficulty in analysis was that each approach would affect different people. That kind of choice cannot be left to professionals, a topic discussed in Chapter 4.)

Now let's take one more step and assume that there is no power company in the picture at this point. No proposal has been made. But there is a projected demand. What are the choices? On the demand side, energy conservation; on the fuel supply side, a switch to another type of fuel or the same fuel in another location.

Solutions to the process aspect might involve an amendment to the eminent domain process so that it would be impossible to employ it until after all permits have been received and all appeal periods to bodies such as the Environmental Quality Board are completed. A second might be to allow the Environmental Quality Board to review need statements as a check for their adequacy. That would be politically difficult. The energy agency was established in the first place to cut the Gordian knot of supply/demand and the environment and the inability to decide. More appropriate might be a requirement for the energy agency to justify a supply-increase strategy as superior to the conservation strategy for granting a need statement. (In evaluating this alternative, it would be found that there is no agency with the authority to implement a demand-reduction strategy.)

These alternatives should be added to Figure 2, as shown in Figure 3.

It would be important to have a compensatory strategy to deal with this problem if in fact the scientific community establishes that the information is inconclusive. There is a tendency for proponents always to look at the good side of data and for opponents to look at the bad side. Political strategies always have to look at the bad side.

Looking at this example, we can see that the amount of time allowed to make a decision or the extent to which the project is in place limits how fundamental one can be in seeking a solution. For a line already under construction, the first line toward causality is as far as one can go. For remaining potential lines not yet started, one could go at least to Level 2, and possibly to Level 3. The argument for going to fundamental solutions that require long lead times and more pervasive support is that once settled, it should remain settled for some time. When the solution is near at hand, very proximate, it is bound to rise again on the next line and the line after that. Some

FIGURE 3. ILLUSTRATION OF ALTERNATIVE STRATEGIES TO BE INSERTED AT THIS POINT.

would argue for operating this way, always at the margin. It has the disadvantage of always looking the next task in the face even though you may prevent it from becoming a crisis. It has the benefit of making no major mistakes. It is merely a marginal shift from business as usual. It doesn't change the nature of fundamental relationships very much.

Finally, it is important in this kind of analysis to stop at some point and ask what is wrong with the present decision-making process that allowed this crisis to emerge in the first instance? Why is it a problem? Solutions to the current problem travel first down the substantive track. If the problem is to be prevented in the future, the process track also will be important.

As an aid to determining whether potential solutions may have been missed, a simple check list is useful. Search for corrective (relocate the line) and preventive (reduce demand) solutions, for capital (bury the line) and noncapital (health insurance) solutions, for solutions within the system (the power line) and outside it (haul fuel by rail).

A second set of crutches or screens for generating strategies involves looking at impacts. Do any of the previous lists adversely affect given locations? Can one think of alternatives that would not have that adverse affect on the poor or other special strata of society? Are there solutions that would tend to balance those impacts? Do the solutions have an adverse impact on other sectors or functions, and are there other solutions that would achieve the same effect without the adverse impact?

These approaches do not cover how to choose which scheme to implement. Rather, they identify what strategies may be appropriate for study. From this one can move to the S&T components of each strategy and the need for potential further exploration of those strategies.

Evaluating Alternatives. This will not be done for the example. It may be unnecessary at Step 2 in the process; it will be necessary in Step 8. Therefore, the focus at this time is to ensure a solid, manageable grasp of the problem only.

It is important to integrate any of these strategies with other decisions and to further link out the solutions to solutions of other leading problems. For example, moving the power plant location closer into the population offers an opportunity to tie into district heating or other means of handling the waste hot water problem that power plants face. If the list of alternatives is too long and a cut is necessary, the following are methods of shortening the list:

You now have a problem statement and a list of alternatives. The situational constraints identified in the public definition become a first screen and a first means of cutting the list.

The second screening is to concentrate first on those strategies that bite at the root cause level and work up the list classifying them according to the cause/symptom chain, from most to least causal effect.

Another way to cut the list would test the effectiveness of each strategy through further quick analysis (see Figure 4). What is the specific technique to be used in implementation — a regulation, an item in a capital budget?

Next, identify whether there is an agency with the legal, technical, fiscal and political capacity to wield that technique. By political capacity is meant the political will to use the technique. In evaluation, the question is whether pursuit of the technique is consistent with past actions of the agency, or whether it goes counter to their normal mode of operation. If the answer to these four agency aspects is "yes," then it is known that the government could do the task if the public would allow it.

Therefore, the next step is the external test or the test for reactions. If government pushed, who would push back? Would there be fiscal, environmental, social or other objections to using the technique in accord with the strategy to solve the problem? If one finds no objection in this test, then it can be assumed that there is governmental capacity to execute and that the strategy will be publicly accepted.

This leads to the third and final test — measure pursuit of the technique against annual goal achievement as derived from the concerns in the problems statement or from a specific objective. This may be measured in terms of percentage achievement, a cost-benefit measure, a cost-effectiveness measure, a social equity measure or whatever measurement is most appropriate to the item at hand.

It should be noted that social problems are rarely solved. Rather, they are resolved at different points in time. The conflicting forces and values are forged into compromises or bargains to stand until such time as another review and another revision are pressed. As such, there are no right and wrong answers. The balance of individual rights versus societal rights is struck year after year, election after election, program after program. That is the nature of much of the stickiest decision making by state and local officials. It is for that reason that the incorporation of scientific and technological information is valuable, but not determinative.

Identify S&T Components. A science advsor, an advisory group or the use of consultants would be useful in each of the three major steps of definition, generating alternate solutions, and evaluating alternatives.

Figure 4

Problem Analysis Worksheet

A problem statement is developed, defined and substantiated with text, statistics and reasoning. It is then checked out in terms of the following points.

Strategy	Course of action to solve or ameliorate the problem; list all reasonable approaches, preventive and corrective, capital and non-capital, in the sector of the problem and other sectors.
Technique	Specific regulation, budget or other legal means to effect the strategy (may be incorporated in the development of a management system).
Agency	Specific actor or actors with authority to employ the techniques.
Internal Constraints	FIRST TEST of problem statement. Agency capability. Legal, fiscal, technical or political constraints or executing the strategy.
External Constraints	SECOND TEST. Fiscal, environmental or social impacts on other agencies or sectors that may constrain execution of the strategy.
Goals	Human benefits related to the problem.
Objectives	Specific measurable effects of the strategy.
Priority Evaluation	THIRD TEST. Goal, achievement, social equity, cost/benefit, cost/effectiveness, etc.

The S&T components will be quite obvious, having reached this level of detail. For example, how and what should be monitored to detect unacceptable change in personal health or the environment? What are the technology and cost of underground transmission lines of this size? What are the known health effects of sustained exposure to such electrical fields? What constitutes sustained exposure? If adverse, are the effects permanent or reversible? And so on, for each alternate strategy. It is obvious from this sampling that the list must be shortened along the line. If the budget is moderate, that may come after the search of existing literature and before the research design for the grant application. If the budget is modest, the cut may have to come before the literature search. By doing this type of simple diagramming of a problem, the risk of not investigating certain items should be better understood and a more informed decision could be made.

Concluding Observations

This process and the techniques can be as simple or as complicated as one wishes to make them. They can be used quickly to sort out potentials logically when a crisis occurs. They can be used with equal success when time and money are no object and a lasting solution is important.

We must recognize that devices based on logic, as the ones above are, have a dampening effect on creativity, whereas lack of a system has the equal disadvantage of potential aimless wanderings or quick coalescence on less than good or less than workable solutions. A balance is struck if the first work on problem refinement and bounding is done analytically as shown, if the second step on generating alternatives is done with a method that induces brainstorming and creativity, and if the third step of evaluation returns once more to rigorous analytical technique.

A second observation is that many of these problem-solving techniques were born in the private sector, as we will see later. Many private-sector decision-making techniques place a premium on time, on getting hands on a workable solution to be put into effect and moving. In the public sector where all such considerations and issues of this importance tend to be public knowledge and publicly debated, pressures are greater to take the best, rather than the first, workable solution. Thus, the argument for techniques that are a little bit more rigorous in logic, though not necessarily exhaustive in research method.

Finally, as will become obvious in the next chapter, problems are most difficult when the concerns identified sort out into conflict between two interest groups. In the case illustrated, the interest groups in contention are those which can actually benefit from completion of the line — power companies — and those which are not benefited by the line — the people alongside who will not use the power. The additional interests, particularly those who would consume the power and who are only indirectly represented by the power company, may vote somewhere in between. They are not part of the decision-making process. Decisions would be easier if the final concerns came down to one type of man-made development vs. another or even development vs. environment, rather than personal health of one group (the farmers) vs. keeping warm for another group (the urban dwellers). The research strategy must be designed to reflect the extent to which a problem can be solved with technical data or ultimately must be resolved through political value judgments. That is discussed next.

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4. RESEARCH AND DECISION-MAKING STRATEGIES

Mel Webber has called the problems with which planners and policy makers deal "wicked" problems.* He defines them as problems in which there is no right or wrong answer and in which value judgments play a major role. In research processes these value judgments imply weights; they also necessitate distinguishing facts from values.

Research on cross-cutting issues or those (previously discussed) that have significant scientific and technological components and implications will almost always require high levels of value judgment. By their very nature, the research and its results will be subjected to the political decision-making process.

Political decision-making processes and scientific research processes are quite different. Since a large number of issues confronting state and local governments today are complex policy questions, there is often a need for scientific and/or technical knowledge in the decision-making process, especially when a premium is placed on reaching rational, highly informed decisions. There is a great interest today among federal, state and local governments in developing and improving the interface between the scientific community and political decision makers. (See the discussion in Chapter 1 for further amplification.)

J. David Roessner, formerly of NSF, in examining the application of S&T resources to state and local government problems, stated:

> . . . federal policy should emphasize strengthened analytic and evaluative capabilities to state and local government rather than the development and use of particular solutions . . . Effective strategies for strengthening these capabilities should focus on those groups and activities toward which state and local officials look for rewards and cues for action, such as public interest and clientele groups and informal, collegial networks.

Irwin Feller, a professor at Pennsylvania State University and a long-established scholar of the intergovernmental science system, has made a similar observation in his research:

> . . .it is doubtful if federal agencies will be able to successfully implement uniform, widely applicable technology transfer or information dissemination programs. Rather, strategies will likely have to be particularistic, flexible and opportunistic. Federal programs and activities will have to be based on detailed "market research" and on theories of search and adaptation, rather than on applications of "classical" models of diffusion and technology transfer processes. (Nelson and Winter 1974; Randor, Feller and Rogers 1978). Moreover, the doubts

raised as to the feasibility of federally conducted strategies tend to enhance the relative attractiveness of strategies oriented towards "capacity building".

The point of relating the observations of these two respected scholars is not to advocate a course of action for the federal government in the area of intergovernmental science, but to identify and relate the emphasis that is being awarded to linking of scientific and technological information to state and local government policymaking processes. This linkage is essential if the scientific community and its resources and information are going to play an integral part in ameliorating the complex multidisciplinary problems and issues that confront state and local government policy makers today.

The Fit of Strategy to Resources — People, Money, Time

A strategy for research and decision making must be explicitly stated so that researchers and public decision makers can concur in the working relationship. In Chapter 3, a procedure was suggested that would ensure seeing the substance of the problem in the same way. Chapter 2 presented a process of conducting the research once the problem was defined. This chapter addresses two more components: (1) the interaction between the scientists and political decision makers during the process of Figure 1, and (2) the decision-making model to be used in arriving at agreements in solving the problem.

Figure 5 displays a range of model decision-making processes from the standard classical rational model on the left to normal decision making on the right. The left side bends decision making to a rigorous method of logic; the right side bends technical input to the needs of the bargainers in the process of decision making. The classic rational model is the normal model taught in planning schools and used by many systems analysts and operations researchers; it is the closest parallel to the scientific method. In it, the sequence is to establish goals, look at all possible alternatives for meeting those goals, evaluate all alternatives, select the best alternative from the set and implement that best alternative. Next to this is a formulation called the alternative behavior or "bounded rationality" model put forward by Herbert Simon. This model is derived from private sector decision making. It does not postulate goals as the first step. Rather, it backs off the classical model in two ways. It looks at the problem and derives a workable alternative, then sets aspirations—a soft way of stating goals — to be achieved by pursuing that alternative. Next, the alternative is evaluated for its potential. If it does not measure up to aspirations, then another alternative may be sought, or the aspirations may be lowered. This is an interactive process, which stops when a satisfactory alternative to meet acceptable aspirations has been found.

The next model is one put forth by Charles Lindblom called successive limited comparison or disjointed incrementalism. Lindblom studied how public decisions are made, rather than how they ought to be made. He observed that they tend to be marginal adjustments from an existing situation in the direction of an improved condition. Lindblom states two main arguments for this approach. First, many public issues are divisive because of their value implications. It may not be possible to obtain concurrence on goals or to obtain it only jointly with the means to achieving it. Thus, Lindblom, like Simon, focuses on strategies and interprets alternative strategies as to their value implications. This system of searching stops when an alternative with acceptable value implications is chosen by the group. The second argument is to avoid the potential for great mistakes that may result from taking long-term unproven steps into the distant future. Lindblom's process relies instead on marginal adjustments that have worked in the past. It further prevents disaster by allowing others to negotiate partisan mutual adjustments to this new changed condition.

In the next step to the right, normal political decision making occurs where there is limited structured input.

Figure 5 indicates some of the characteristics of various models — the time required to make a decision, the information costs and, therefore, the analytical cost of arriving at a solution, the extent to which the process constitutes an intrusion in exsting private and public-sector descision-making processes and so on.

For example, the time available for a solution with the resources that can be brought to bear may call for a short-cycle, "tap experts" strategy as indicated in Figure 1, using a classical rational model. Alternatively, the same resources may be allocated to a mid-cycle, "tap the literature" strategy using a less comprehensive Simonesque or Lindblomian model.

The Fit of Strategies to the Value Content of the Problem

If the issue is very value laden, then classical rational methods can deal with it poorly at best. When, as mentioned in the power-line case, the choice in the problem is between competing value sets of two affected population groups, classical rational aspects or analyses dealing with the theoretical substantive aspects of the problem, rather than the "real" problem as perceived by the affected parties, will come to little.

Figure 5 SPECTRUM OF MODEL DECISION-MAKING PROCESSES TO BE INSERTED HERE

The research and decision-making strategy must link the problem as perceived to the more fundamental problem as deduced from analysis.

To more fully understand the implications of defining such strategies, the relation between scientific and political approaches must be seen. We can categorize science from hard to soft, with hard science being physical, social science next and the softest being the policy sciences. Those in the physical sciences tend to equate their field with the term science. To them, sociology, political science and the softer sciences are not science but social sciences requiring the clarifying adjective. Many would also deny that there is such a thing as policy science. But we cannot ignore the fact that there are an increasing number of academicians and professionals who are pursuing the study of policy making and implementation using scientific methods. In other words, they are establishing testable hypotheses and proceeding to set up tests to prove or disprove those hypotheses.

The reason for calling these hard to soft is that the physical sciences have more solid laws and principles based on known cause-and-effect relationships. That solidity of cause and effect diminishes as one moves from the physical sciences through the social sciences to the policy sciences. On the other hand, the policy sciences are more attuned to the political process, the making of trade-offs and value judgments. Social science is next most sensitive to the ways of political decision making and the physical sciences least.

That leads to a set of cautions for system design or for system users. If the problem definition or solution is likely to require a high degree of value judgment, one can expect increasing difficulties with the scientists as one moves from the policy sciences to the physical sciences. The processes of participation by the scientist, releases of results and similar matters should be designed with more care.

Research is likely to be difficult to manage when the most appropriate research strategy is the left side of the model and the most appropriate decision-making strategy is the right side. That is the reason for looking at strategy at this point — to ascertain how the two will be linked together. It is unlikely that any project will be developed for federal funding through this mechanism that is at either end of the scale. If the problem is at the extreme left end, and the solution is essentially a technical one, the politicians are unlikely to be involved. On the other hand, if the solution is at the extreme right end and involves virtually no input of scientific and technical information, it will not be the basis for a grant request. Therefore, the majority of problems using federal R&D funds are likely to fall in between. They will be problems requiring intuitive analysis as well as more rational analyses.

The extent to which value judgments are important determines the points and nature of interaction between the research process and the political decision-making process. This is illustrated in Figure 6. For example, if the item is not a pressing crisis, it can be investigated through a research project. And if the answer is not highly emotional, it is unlikely to be divisive. The process, then could involve minimum interaction with the decision-making strategy, touching base only at the point of problem definition, redefinition and recommendation in steps 2, 6, and 9 of Figure 1. On the other hand, if there is a high degree of value judgment involved in the issue, and technical information is essential but not determinitive, then a high level of interaction would occur between both parallel streams at all points throughout the work.

FIGURE 6 RELATION OF RESEARCH PROCESS TO DECISION-MAKING PROCESSES TO BE INSERTED AT THIS POINT.

Relating Research to Implementation

It is likely that all these research projects will be oriented toward implemented solutions rather than academic ones. Therefore, it is important that the implementation of step 10 (see Figure 1) be part of the discussion no later than step 6 and desirably in step 2. This means both who will be involved and the strategy for the implementation. That is, how will the implementers be involved with the research effort, and how will the various interests be involved and kept informed in the course of decision making. One obvious guideline is that as the clash between interests increases, as in the power line illustration, the more important it is that the various interests have access to findings as they occur.

The mechanism described in this Handbook for employing federal research and development funds at the state and local levels to solve problems of mutual concern is part of a larger framework for employing scientific and technical information. Figure 7 illustrates this larger framework and the relation of several current endeavors.

This Handbook is concerned with the three components of problem solving (Identification, Definition and Solution) as they relate to new research employing support from federal R&D and S&T resources.

Figure 7 illustrates three approaches to problem solving. Tapping the knowledge of experts may lead to the literature search and that in turn to new research. Also, a literature search (particularly tapping the current Smithsonian Science Information Exchange) may lead to candidates for a panel of experts. Each approach, however, involves the components of the Identification, Definition and Solution.

The ISETAP program is addressing problem definition. The SSET program is intended to build state and local capacity to undertake all three components of problem solving employing any of the three approaches as appropriate.

Figure 7

Three Approaches to Problem Solving

To solve problems involving scientific and technical considerations, an agency may use one or more of three approaches.

1. TAP EXPERT'S KNOWLEDGE or	2. SEARCH EXISTING LITERATURE or	3. UNDERTAKE NEW RESEARCH

to do this it may.....

a. employ staff	a. standard library search	a. The subject of this Handbook
b. employ consultants	b. NTIS search	
c. set up a committee	c. SSIE research	
d. conduct an AISLE type seminar	d. the subject of the next chapter	
e. etc.		

In setting up the work under any of the above approaches, problem solving involves three components, as follows: Identification, Definition and Solution

5. HOW TO IDENTIFY EXISTING KNOWLEDGE OR ONGOING SCIENTIFIC RESEARCH

In this chapter, we want to identify methods for conducting certain kinds of manual and automated searches of various data bases dealing with scientific research and development. After describing those methods, we shall have a few things to say about the context in which such searches are conducted.

We have devised methods at several levels of sophistication and we shall take these up one at a time, beginning with the least complicated

The first method is a manual search system.

Manual Search

The manual system involves use of the Catalog as set forth in Part III of this Handbook.

Use of the R&D Catalog. In this manual system, the Catalog's key word index and program finder can be used to quickly locate federal programs which may offer various kinds of support to local and state governments having complex and cross-cutting problems with scientific and technical components.

The key word list is composed of 11 broad categories, each of which has been subdivided into a series of functional topics or activities. The list of categories and subdivisions has evolved from state and local government statements of problems and needs currently being developed by the National Conference of State Legislatures and ISETAP.

For each of the 150 subdivisions of the key words , the program finder index lists those federal programs (if any) that can possibly offer support. This support may come under one or more of the following categories:

- o Transfer of funds to perform research and development activities;
- o Transfer of program funds with potential for research and development support;
- o Transfer of scientific and technological capability; and
- o Redirection or adapation of federal R&D and S&T activities.

To access appropriate federal programs contained in the catalog, identify what you consider to be the most important words to describe the problem area under consideration. Next, select the key word(s) and subdivision(s) which most clearly relate to your descriptive words then turn to the program finder to determine whether or not any federal programs exist which might offer help.

When the programs have been identified, turn to the body of the Catalog itself and review the information provided for each of the federal programs to determine which potentially offer support in any of the four categories mentioned above.

In almost all cases, the key word index and program finder will allow state and local government officials and staff members to quickly identify those federal S&T-related programs contained in the catalog which may be of help. In a certain number of instances, however, state or local government personnel will not be able to fit their problem into one of the activity areas. Or, it may be necessary to identify ongoing and recently completed state-of-the-art scientific research related to the problem or issue at hand. In these instances, a literature search, whether manual or automated, will be necessary.

If the key word or topical subdivision has been identified, it can be used as a point of departure for state-of-the-art research. In this way, the key word index can be used to build a bridge between appropriate federal S&T-related assistance programs contained in the Part III catalog and existing knowledge and ongoing research pertaining to the issue. In situations where a match cannot be made between a problem or issue and the Catalog's key work index, use of the SSIE Subject Terms and Synonyms list as a starting point for a state-of-the-art literature search. State-of-the-art research is dealt with under SSIE Custom Search below.

Absence of Aids to Manual Literature Search. This Handbook does not provide any aids to the conduct of a manual search of the literature. While we believe that manual searches to identify existing knowledge and ongoing research can be appropriate, we know of no way to conduct such searches which does not depend on the skill, training, experience and motivation of the person performing the search.

There is no ready way of providing state and local government with such persons. Training by itself will not meet the needs these governments might have.

If such searches are needed, the state and local governments will either need to use consultant organizations which provide these services for a fee, or the governments will have to hire and train staff persons.

Where existing government staff members are experienced in these kinds of searches, we believe such searches will be useful and important, either in lieu of automated searches or as a supplement to them.

Automated Methods

In order to identify existing knowledge and ongoing research about the scientific and technical components of complex and cross-cutting problems, we are proposing that state and local governments make use of some existing information systems.

We believe that the first information system which state and local governments should consider using is the Smithsonian Scientific Information Exchange. For users who have only infrequent need for information retrieval, we recommend the use of SSIE's Custom Searches.

SSIE Custom Search. An SSIE Custom Search is conducted by SSIE's information scientists on the basis of an individual request from a user. The subjects to be searched for can be broad or narrow. In addition to subject criteria, the search can be conducted for administrative criteria (i.e., individual researchers, particular organizations, departments or geographic areas). The search results are reviewed by the SSIE information scientist, and if futher guidance is needed for the user, the SSIE scientist will call the user on the phone to obtain it.

The SSIE Custom Search is made in the SSIE data base, which contains notices of research projects for the most recent two years. These notices (called NRPs) are provided by more than 1,300 federal, state and other agencies in the United States. At present, the data base contains more than 200,000 such NRPs. The NRPs describe ongoing research projects.

SSIE can also search its historical files back an additional five years (a total of seven years for the two data bases) and can search the National Technical Information Service (NTIS) files as well (for a somewhat higher fee).

Advantages of the SSIE Custom Search. The SSIE Custom Search provides a means by which any state or local government can obtain a sophisticated search for ongoing research and for reports of federal research completed. The fee for this service will generally be less than $100.

The search will require only that the user be able to state what the problem is. The SSIE information scientist will select the appropriate hierarchical subject terms. Where there are problems in selecting these terms, the user can confer directly with the SSIE information scientist to assure that acceptable terms are used.

The user requires no knowledge of the hardware or software needed for the search process. No special training of the user is required. The only equipment required is a telephone to talk to SSIE (although mail requests will also be honored).

The search can be conducted on a same-day basis (for an additional fee), and for a slight extra cost the results can be mailed within 24 hours. Users who have access to a computer terminal that can be coupled with a telephone can have the results of the search printed out at their own locations.

Searches can be updated with new material on a periodic basis if the user desires this service.

If the user wishes, he or she can suggest that the search begin by using one or more of the topics contained in the key word index in the Part III catalog to access to information. Or, the SSIE Subject Terms and Synonyms list can be used to identify appropriate terms for use in a search.

The SSIE list is a hierarchical listing of some 40,000 subject terms and an additional 50,000 synonyms or subordinate terms, all in a single alphabetical sequence. These terms are all subordinate to several hundred major subject index categories used by the Smithsonian Science Information Exchange.

The SSIE Subject Terms and Synonyms list is available in the form of a three-volume computer printout from the Smithsonian Science Information Exchange, Inc. for about $50.00. (SSIE's address is: 1730 M Street, N.W., Room 300, Washington, D.C. 20036. Telephone is: 202/381-4211.)

To use the hierarchical subject terms list, identify what you consider to be the most important words to describe the problem area under consideration (the components of the complex and cross-cutting policy problem).

With these words, enter the hierarchical subject terms list. The list is printed in such a fashion that as soon as a word is found in the list you are led immediately to the major subject index category under which it is classified (e.g., if you look up "water reuse", you are led immediately to the major subject index category of "water resources").

The major subject index category can be used as a starting point for research by the SSIE information scientists.

SSIE and Other Data Bases On-Line. For searching the existing scientific literature, state and local governments may wish to make use of the existing data bases which contain references to such literature.

There are more than 300 such data bases in existance in the United States at the present time. Many allow users to conduct searches on-line. The data bases often contain 10 years or more of references to particular journals, and hundreds (probably thousands) of journals, reports and other document serials are now contained in the existing data bases.

We have reason to believe that private firms are prepared to offer custom on-line searches of these data bases to state and local government clients. Otherwise, it will be necessary for users to learn how to conduct the searches themselves. Since it is estimated that nearly 1.7 million such searches were conducted in the U.S. last year, the expertise necessary to supply the service to state and local governments should be readily available.

Tentatively, it is recommended that governments consider the Lockheed Information System (LIS) and the System Development Corporation (SDC) services because they are the most comprehensive in terms of data-base size and journal coverage. For some particular problems, other data bases may be of special interest. These data bases might be identified by a search of any one of several standard references on the existing data bases.

The American Society for Information Science has published a comprehensive directory of available data bases entitled Computer-Readable Bibliographic Data Bases — A Directory and Data Sourcebook. This directory, prepared by Martha E. Williams and Sandra H. Rouse of the Information Retrieval Research Laboratory of the Coordinated Science Laboratory at the University of Illinois, should be available for use at most university libraries.

High Volume or Sophisticated Users

For state and local governments which need frequent searches or which are already sophisticated, it seems that installation of appropriate terminals would be cost-effective. By means of such terminals, the government could gain access to the existing data bases, conduct their own searches and receive printouts of the research results.

Such an installation would require start-up costs for hardware acquisition, personnel hiring or training, and perhaps related facility acquisitions. There would also be charges for use of the data base and network charges (to such firms as Tymshare or Telenet).

While there may be many situations where such costs could be justified, it is recommended that governments go slowly in moving to such a pattern of use. Such installations should be created <u>only</u> when it is clear that they are needed and that they will be cost effective.

Current Awareness Searches

A number of information searching and retrieval organizations provide reports on a wide variety of topics in the area of scientific and technological information. These reports are done on topics of current interest and are updated periodically, usually several times a year.

If the topical searches available in this form are in areas of interest to problem solvers, then these packages can be an inexpensive way to gain an idea of the latest work being done. They constitute, to some extent, a substitute for custom searches done either in-house or by some service organization.

The United States Department of Commerce's National Technical Information Service is working toward the development of such search packages in areas it believes will be particularly relevant to the concerns of state and local governments.

Using the Results of the Search

The results of the search effort will usually be summaries of ongoing or completed research work. The summaries will provide brief information on who is doing what work, where it's being done and what results, if any, have been achieved. Details about the work will be missing. Although these summaries will probably provide enough information to eliminate some projects from further consideration they are unlikely to contain enough detail to permit making good judgments about what has been achieved by projects that look interesting.

To do the kind of careful study that often will be required, it will be necessary to obtain copies of the original books, journals and papers to which the summaries refer, or it may be necessary to contact the researchers who are doing or have done the work described in the reports. This follow-up will usually take some time.

If there are major research institutions nearby, it may be possible to work through them to obtain copies of needed printed materials. Phoning the investigators who did the work will often be the most effective way to find out whether their efforts have any relevance to the problem which prompted the search effort. Such calls may also be used to obtain copies of hard-to-find documents. Where time is critical, the telephone may be the only way to obtain information timely enough to be of use; in such cases, the cost involved in its use may be trivial compared to the costs of making the wrong decisions or pushing unfruitful lines of thinking.

Interpretation

Understanding the scientific and technical literature and interpreting its meaning for a particular complex and cross-cutting problem seems to present special difficulties. We believe that it would be wise for state and local governments to make use of suitable and carefully selected scientists, engineers and other technically qualified persons to assist in making these kinds of judgments.

Such persons may already be part of the staff on the agencies trying to solve the problem. If they are not, arrangements should be made to obtain their help for as long as they may be needed. If they are carefully chosen, it should be possible to rely on their advice with some confidence.

It is neither practical nor appropriate to describe here the kinds of processes such persons should go through in evaluating the "state of the art" in a given research and development area, but it should be emphasized that making such interpretations requires skills and experience of a very high order.

The costs of obtaining sound advice in making such interpretations will be more than justified by the results.

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6. MANAGING MULTIDISCIPLINARY RESEARCH

This topic is a complex one, which cannot be treated adequately within the space available. To do any justice to it, a series of related topics must be excluded at the outset.

First we shall not attempt to describe how to conduct research within a discipline. We assume that social and natural scientists are trained to do research and that no further guidance need be offered.

Second, we do not propose to offer any general guidance here on how to conduct research in the broadest sense of that word. We presume that in the course of training and experience in their disciplines, those who may become part of a multidisciplinary team have received training in the general process of research.

Third, we will not discuss the general process of managing research, even though much less useful information available on this topic than on the two just mentioned. Later on, we suggest that the most useful way to ensure good research management is to secure the services of a good and experienced research director.

What we will take up in this chapter are the features of managing multidisciplinary research which we feel are specific to multidisciplinary research — that is, those features which will not be found at all, or will be of lesser importance in the management of disciplinary research. Multidisciplinary research is different from disciplinary research, and managing it effectively requires some special skills and insights.

Definitions

Because of the diversity of meanings attached to words like "multidisciplinary" and "interdisciplinary," it will be useful to define these terms. For the purposes of this Handbook, a "discipline" is a rather distinct body of knowledge. Persons working in a discipline also receive a distinct background of training and experience. Biology, sociology, biochemistry, internal medicine, astrophysics and similar fields might all be considered disciplines within our meaning of the term.

We will use the terms "multidisciplinary" and "interdisciplinary" interchangeably. For either word, as applied to research, we assume that the research is carried out by persons drawn from two or more disciplines and that each person so drawn is <u>functioning</u> in a role appropriate to his or her discipline's background and training.

In what is to follow, we shall usually assume that an interdisciplinary <u>team</u> of researchers is involved. The team will be most useful if it is located in one place and works together on a project. Nevertheless, the advice offered would apply to such a team even if its members were scattered or met only infrequently.

<u>Features of Multidisciplinary Research</u>

Enumerated below are some of the features which characterize interdisciplinary or miltidisciplinary research, distinguishing it from research within a single discipline or as different from group research in which the disciplines are all identical or nearly so.

First, multidisciplinary research brings together individuals with often quite different <u>conceptual systems</u>. That is, the members of the team may see the world from different perspectives and may understand events from different points of view. This is one of the great values of multidiciplinary research. A sociologist and a physician, for example, are likely to see public health from two different points of view; that is what we are looking for in taking a multidisciplinary approach to public health.

Multidisciplinary research brings together persons whose <u>interests</u> (often somewhat apart from even their disciplines) are different. For example, engineers and physicists will probably be interested in construction or in machinery <u>from somewhat different points of view</u>. Some differences between the disciplines go to the affective, emotional and like levels of behavior. An ecologist often will <u>feel</u> differently about an environmental situation than will a psychologist or an engineer. As problems are chosen for study, different disciplines will look on them with varying interests and feelings. Often these interests will condition the willingness (and certainly the eagerness) of various team members to work on a problem. Managers should be aware of this and take it into account in their planning.

Some of the disciplines which may be brought together in a team will be competitors on most occasions, often for scarce resources (such as research funding). This means that something like adversary relationships may be set up even before the team is put together.

Both the disciplines and the individuals who practice them will come to the team with differences in status. A psychiatrist, for example, will generally be accorded a higher status than a psychologist because of training, income and the kind of setting in which each works. Molecular biologists these days are probably accorded higher status than are taxonomists. These differences in status will influence the function of the team and of its individual members (even though they should be irrelevant).

The persons on the team will each bring with them their own stereotypes, ideas and expectations about each other's disciplines. Getting through these may take some doing and may interfere with the functioning of the team, at least in its early work. This means, as we shall suggest later, that it is important to try to get through these preconceptions as smoothly as possible. It is important to realize that some of these ideas come from the kind of training and experience that is part of the discipline. The very conduct of research itself breeds these ideas and the feelings that go along with them. Chemists and physical chemists must sometimes wonder at the kinds of problems which biologists undertake to study; biologists and psychologists probably look at problems of behavior through different eyes. These differences lead to stereotypes about both the disciplines and those who practice them. In managing a group of researchers who may have such stereotypes, in designing a common approach to a research problem, difficulties are almost inevitable.

There will be substantive differences between the disciplines in methodology, approach to methods of conducting research, means of analyzing data, publication of results, and in other areas. These differences will be ones in which the disciplines have a considerable stake and about which compromise will be difficult or impossible to obtain. In some cases, these differences will require that the disciplines proceed along their own lines, with only the results of their work being communicated to the group. It will be important to define these kinds of differences during research design and to account for them in the planning and execution of the project.

At some place between the emotional and affective and practical and operational will be the area of the philosophical and ideological. The disciplines will probably differ in these areas, too. Evolution is interesting to a sociologist, but to a geneticist or a taxonomist it is an essential and central way of looking at all living things and how they interact. Freudian psychology may be of no interest at all to an engineer, but may be a dominant factor in the understanding of a psychiatrist. These kinds of differences mean that in daily conversation, in the give and take of group meetings, and quite possibly in serious decision making, the team members will come at things in fundamentally different ways. While this is one of the reasons for doing interdisciplinary work, it is also a cause of difficulty in its execution.

Each of the disciplines will probably have its own rather specialized vocabularies and definitions. This will first mean that a good deal of "translating" will have to take place. (We will return to this subject later.) It also means that in some cases the same words will be used with quite different meanings or connotations. The team members will have to be aware of this constantly and allow for it in their communications.

To some extent, we can summarize this list by saying that interdisciplinary or multidisciplinary research is really a kind of cross-cultural experience. The practice of a good many disciplines (especially of research in the disciplines) places an individual in a very special culture with customs, norms of behavior and ways of thinking that are quite different from those of society as a whole.

This needs to be kept uppermost in the mind when thinking about management of teams of researchers on a multidisciplinary research project.

Design of Interdisciplinary Research Projects

The first question that should probably be asked is whether interdisciplinary team research is really required to solve the problem. Research by an individual, or research conducted by a group of workers from within a single discipline or a fairly homogeneous group of disciplines, will be much easier to conduct. Another alternative would be to find a single individual, or a few individuals, who are themselves trained and experienced in more than a single discipline. It might be possible to cut the problem up into pieces, so that each of the individual disciplines could work in comparative isolation from the others during the research and only combine in presenting their results.

If it is necessary to use interdisciplinary (multidisciplinary) team research, the interdisciplinary aspects of the research must be carefully weighed against the single disciplinary aspects at the outset. In most projects where a team is needed, there will be portions of the problem which can and should be attacked entirely by individuals from a single discipline.

Because of this need to balance single-discipline and multidisciplinary research interests, one approach to the design process may be to involve the various disciplines chiefly during the initial design phase and then later during the process of interpreting the results of the research effort. In between these times, the work should be done by persons in single disciplines and by a multidisciplinary team where that was required.

To obtain the proper balance of interests, it might be appropriate to gather persons from the needed disciplines, explain the problem to them, let each of them design his or her own approach to the problem, and then get them together to critique one another's work and come to some agreement on whatever joint work is necessary. This might have the advantage of minimizing the interdisciplinary work required as well as insuring that whatever team research was needed had been done with the advice of the persons to be involved in it.

There will be some kinds of problems where a team will definitely be required. Perhaps the most compelling example of this would be a case in which simultaneous work needs to be done (e.g., a single event must be observed simultaneously by persons from several disciplines).

Sometimes it is argued that teams can provide more efficient results. This is true only if two persons working together can produce a result more efficiently than could the same two working individually. Because of the problems with team research, teams are often less efficient than are individuals. This should be borne in mind.

Where an interdisciplinary team effort is clearly indicated, the means for efficient design must be employed to provide for the most effective joint efforts.

Since each project will present different problems, it is not possible to give much useful advice on the specifics of project design beyond these points.

Composition of Multidisciplinary Research Teams

Closely related to the question of the design of the research project, indeed inseparable from it, is the decision about which disciplines will be required to take part.

The team should be kept as small as possible and the number of different disciplines involved should be kept to a minimum, in order to minimize the problems of organization and execution of the research.

Wherever possible, the disciplines selected should be compatible at a theoretical level. That is, they should be ones that can be expected to work together in harmony, at least at the level of overall philosophy, theory and approach. Some disciplines are probably more compatible with one another than are others. Physical scientists are accustomed to working together on problems; they are only somewhat less accustomed to working with life scientists.

The time at which decisions about team composition are made is important. It is important that disciplines which are brought in should have an important role to play in the project. Selecting disciplines "so that everybody is represented" is both operationally and theoretically unwise. It is also unwise to be put in the position of having to add disciplines midway through the project "because we didn't realize how important" they would be.

There are two extreme positions which can be taken with regard to the selection process and the attendant planning of the research project. The first would be to select all the disciplines to be involved at the outset, and involve them in the entire planning process. At the opposite pole is the idea that a project should be entirely planned <u>before</u> the various disciplines are involved.

If the disciplines are selected first and involved in the planning, it is likely that the problem itself will be formulated in broad and comprehensive terms, and that the concerns of each of the individual disciplines will be well represented. This joint planning may also result in agreement on the project from the beginning and provide for better communication throughout the life of the project. On the other hand, this joint planning may <u>not</u> result in consensus (often a pseudo consensus is achieved that is worse than none at all), the individuals involved may inhibit one another's thinking, and the plans may be worse than if they had been created by a single individual.

If, on the other hand, the project design is formulated first, it may be easier to recruit team members (since they will know what they are getting into), and those who do join the project will have clear expectations of what their roles and functions will be. The disadvantages of such an approach are that such a design may lack comprehensiveness and intrinsically may <u>not</u> be interdisciplinary. Researchers brought in later may be limited to correcting the mistakes of the original design and may be unable to compensate for basic flaws in the project conception.

It may be possible to combine the best of both approaches by having a single person design the project and having the design reviewed by experts from each of the disciplines to be involved (and perhaps from others that <u>might</u> be relevant). After this is done, the actual team members would then be recruited and the design put in final form.

Whichever approach is used, it is important that the <u>director</u> of the project (and perhaps key team members) be involved in the project from the design phase onward.

Selection of Individuals for the Team

Deciding who will be on a team is as important to the success of the project as selecting the disciplines to be involved. Often the selection of the team members is even more important

In this section we shall discuss the general characteristics of any team member. These considerations will apply especially to the team leader or project director. We shall have additional things to say about the director in the next section.

First, it goes without saying that one would like to obtain the best researchers available for any research project, all other things bing equal. In the case of team research, however, "all other things" may not be equal. Team research places a special importance on the ability of an individual researcher to communicate with other members of the team, often acting as a "translator" for his or her own discipline. This role may be of such importance that a person with those skills should be preferred to another with superior experience and accomplishment in research.

With respect to communication, the particular qualifications needed in a team member fall into three general categories: professional training and experience, personal characteristics and personality, and motivation to participate in interdisciplinary work.

Training and Experience. If at all possible, persons with previous experience in interdisciplinary team research should be preferred in selection. This is a wise procedure, because it guarantees that the individual has "been through the mill" in this kind of project and has probably worked out methods of coping with problems that are peculiar to multidisciplinary work. Additionally, such persons may represent a self-selected group who are more willing or more able to function well in this kind of situation.

While it will be rare, it would be especially valuable for a person to have been trained in a setting where multidisciplinary work was done.

Further, certain individuals may have worked together on previous projects. If the collaboration has been successful, we would recommend considering the use of the same team, augmenting it as necessary. This has the great advantage that no break-in period will be needed, that the individuals will already have established effective working relationships, and that they may already have developed processes for catalyzing one another's thinking. Where a group of kindred spirits can be found, this advice especially applies. (Where a consultant group is used, such a functioning team may be available almost intact.)

If neither of these two kinds of experience is available, it is at least important to consider the kinds of methods that the individuals are accustomed to. Experience with group research would be useful, for example. Experience in communicating with others, in dealing with problems which involve more than a single discipline, in using techniques where the individual must deal with persons from other disciplines — all these would be useful kinds of experiences. Where an individual is being added to others already selected, the compatibility of the individual's experience and methods should be considered. Becuase of the importance of achieving the right team "chemistry," the selection of each successive person will need to be based upon somewhat differing considerations. This will need to be done to obtain the required balance, the proper blend of personalities and abilities, and so on.

Personal Characteristics and Personality. If the services of individuals who have already proven themselves in interdisciplinary team research cannot be obtained, it may be necessary to select individuals based on personal traits which seem conducive to success in such situations. Some of these are listed below.

Team members should be able to tolerate the greater frustrations which are characteristic of all group research and which are particularly characteristic of multidisciplinary team research. Working with a group involves compromises, the need to discuss and explain, shared decision making and many similar kinds of activities which take time away from the actual research. This is frustrating to many researchers, especially those accustomed to running their own shops in their own ways. Tolerance for this kind of frustration is important. A lack of such tolerance may be a prime factor in steering some researchers away from all group projects, especially these where other disciplines are involved. There are, on the other hand, individuals who seem to find these kinds of situations especially stimulating.

It is important that persons representing a discipline on a team be both professionally and personally secure. It is characteristic of such research that questions about one's approach, the basis for one's decisions, the soundness of one's methods are going to be raised. Worse still, we are likely to discover the shortcomings in our own training, experience, insights, etc. It is the purpose of multidisciplinary research that this should happen. If, when this occurs, the individual researcher responds only defensively or feels personally or professionally threatened, the very process of interdisciplinary team research comes to a halt. It is precisely at such times that the value of this approach becomes clear. If the individuals on the team withdraw into protective shells, the process will stop. To avoid this, the team members must feel secure enough to accept criticism and deal positively and creatively with it.

Akin to the previous need for security is the need for emotional maturity. If an individual on a team is to treat criticism positively and offer it constructively, he or she must be mature enough to function without the game playing into which critcal analysis can degenerate. That is, team members must be able to offer and accept criticism, advice and correction without taking it as personal or petty attack.

Moreover, because team research inevitably involves a great number of learning experiences, the team members must be prepared to alternate readily between roles (student and teacher, master and pupil, and so on). They must be able to accept this often-rapid alteration of roles with equanimity and, it is hoped, with a sense of humor. They need to be docile — teachable — at such times, prepared to learn from others on the team and prepared to teach, if we may paraphrase Alexander Pope, without lecturing, imparting things unknown as things forgot. The value of such maturity in dealing with all the normal strains of research (failure, equipment breakdown, insufficient funding, prolonged delays, etc.) should also be apparent.

Team members should be flexible. This is commonly suggested, but what is meant is not always clear. In the present context, we mean that they should be able to respond to criticism in ways which are both faithful to their own disciplines and faithful to the pursuit of the problem solution as well. The former is the easier of the two; the latter may require that they sometimes adopt methods and approaches which are quite uncommon among persons with their background and training. If they are rigid, such altenations in approach and method may be beyond their capabilities or even beyond their thinking. It is essential that when they see the value of a different approach, they are able to adopt it even if it is foreign to their previous background and experience. Flexibility in thinking is just as important. A biologist, in order to function on the team, may have to understand (at least up to a point) how a psychologist thinks about a problem; a sociologist may have to try to see the world through an anthropologist's eyes.

Humility, in the best sense of the word, is important to every member of the team. While there are other definitions, we would define humility here as "being truthful about everything." The implication of this definition is that the individual is prepared to admit freely when he or she has been in error, and is prepared to be led to the truth wherever it is to be found. This is a rare trait in people, but it is one that is especially important on an interdisciplinary team, where so often we discover that our accepted notions about things are either erroneous or at least incomplete. Humility in such situations is akin to the docility mentioned above. Where the truth uncovered is not what we prefer, a certain amount of personal moral courage may also be required in seeing and describing what has been found.

Open-mindedness is closely akin to humility. It may have somewhat more to do with attitudes than with facts, however. Open-mindedness may imply a willingness to listen to arguments even when they do not have much truth in them, perhaps simply for the sake of hearing the other person out. Fairly often, the truth is uncovered in this way. We begin by listening to an argument in order to be fair (or polite) and end by being convinced, often against our will or preferences. Open-mindedness may be the handmaiden of humility in such situations.

Along with the self-respect (personal security) which we mentioned above, it is essential that the team members have respect for one another and for one another's disciplines. The latter (respect for another's discipline) is not such an easy thing as non scientists might suppose. The training of researchers in graduate institutions is designed to foster an extremely critical attitude, necessary in one who is committed to finding out the truth about matters in which the truth may be extremely hard to dig out. This attitude begins with critical attention to one's own work and extends to an often-biting criticism of work within one's special field. Scientists can feud over questions related to research in the same way that nations feud over national interests. Given this situation, it is no surprise that there is often a pecking order within disciplines with certain specialties considering themselves superior to others in the practice of their art. Thus, it is commonly suggested (and often true) that surgeons consider their work to be superior to that of internists, or that some kinds of surgeons consider their skills superior to those of other kinds of surgeon specialists. This feeling may be intensified when one discipline compares itself with another.

Genuine respect for other disciplines and those who practice them may thus not be easy to find or, if found in an individual, may be a sham. It may be more likely in persons of experience and maturity. If it cannot be found definitely in a prospective team member, then open-mindedness may be a reasonable substitute for it. To an open-minded person, part of a team of sound professionals, the needed respect for other disciplines may come in time, even if it is not there to begin with. Tolerance may also be a substitute for mutual respect and may lead to it in time.

Related to respect of other disciplines is a high level of tolerance for ideas which are foreign to one's own training and background — concepts from other disciplines. These concepts may range from basic philosophy and ideology (Freudianism, Darwinism, etc.) to simple differences in ways of describing or discussing data. These differences can get on one's nerves and result in demands that the team "clean up this fuzzy thinking." The ability to tolerate these differences and the ambiguity that results from them is important to the smooth functioning of the team.

The team members must also recoginze the limits of their own disciplines; this is related to the point just made. At times, specialists may act as though there was no world outside their own. What is required for interdisciplinary team research is a recognition that other worlds exist and that there are many things about them which we do not know. A good team member should be aware of the theoretical limits and the methodological or technological limits of his own discipline. The latter are important at the time of experimental or observational design. When the discussions start, it will obviously smooth matters if each person involved has a fairly clear idea of what his or her discipline can contribute and what it cannot. If each does not, then the boundaries will have to be drawn by means of discussion, demonstration and argument, which will take additional time. (We shall assume here that the task of pushing out the borders of the individual disciplines is best left to researchers other than those on interdisciplinary terms of the kind we are discussing.)

Each of the team members should have a desire to learn. This will mean a desire to learn from the others on the team at least; it may also mean that the individual should be prepared to learn enough more about this or her own discipline to supply the sometimes unusual demands of the interdisciplinary research project. It is the common experience of persons in interdisciplinary projects that a lot of "going to school" is involved. It has been suggested that one result of such projects is the creation of educated amatures in the second field. A biologist becomes a rather good amateur physicist; a sociologist, a good amature psychiatrist. Often, much of the time of the project is taken up by gaining these kinds of new knowledge. It seems that such reeducation is important to the proper functioning of the team and its members. Therefore, each team member must be ready for reeducation (and even eager for it). Obviously, some balance must be maintained. The objective will not be for the sociologist to become a psychiatrist. What is required usually is that the sociologist come to understand enough about the psychiatry involved in the project to be able to relate well to it as a sociologist. So what is wanted is interest and willingness to learn, coupled with a sense of perspective and a clear understanding of one's role in the project.

Each team member should have a clear understanding of his or her own personal strengths and weaknesses. In any team effort, there is going to be some jockeying around in order to find each person's most suitable role on the team. There will be inevitable competition for certain roles and functions. It will be most efficient if the individuals on the team have some idea of what roles they can play before this process starts. In this way, useless struggling over roles and turf and be avoided. Also with an idea of our own abilities, we can contribute most effectively to the rest of the team. In particular, when we come to a soft spot in our own training, experience or approach, help may be found within the team. If a team member is aware of a weakness in statistics, he or she may be able to find someone with expertise in that area elsewhere in the team membership. It will also be necessary to know when to be assertive because of one's special knowledge, experience or insight. It may, in fact, be useful for the team members to do a certain amount of soul searching before the project, and for the group to exchange information about experience and training in a rather formal way at the project's start.

Each team member should really enjoy working with people. In a team research project of any kind this is necessary; it is more necessary when the team is made up of persons from quite diverse backgrounds. The individuals should be able to derive some of their satisfaction just from being around other people (i.e., it is probably not enough that they be satisfied with using others to accomplish a task; they should also be interested in others for their own sake, as persons in their own right, quite apart from their professional roles). This interest in fellow team members will smooth the work of the team; it will also make for a better feeling throughout the project which may contribute to the quality of the work. A good many projects succeed in part because of the mutual desire of the team members to do well, not so much for the sake of the project as for the others on the team. If such a spirit can be fostered, the project will be the better for it.

We are not prepared to say how to discern whether an individual really likes working with other people. This is a function which the project director will, however, either need to perform or have preformed by someone else.

It is important that each team member be able to communicate clearly about his or her own discipline. This is not evidenced by publications or textbooks written so much as by the ability, across a coffee table, to make clear in discussion what the discipline has to say about a series of topics raised in a disconnected way. Most mutual education of the team will take place in very informal ways. The blackboard may be beach sand or a table cloth. There will be no textbook. The teacher at one monent will become the student in the next, and the roles will be exchanged frequently. Team members must have a strong desire to communicate about their disciplines (we would suggest they should be bursting with it, except that this can at times become a bit tedious) as well as having the skills necessary.

This ability to communicate is absolutely central to team research. Most of the traits which we are proposing for team members are related to it.

It is important that team members be able to translate from their present training and experience to the problem at hand. Rather than being able to see the problem only from their present point of view, the must be able to look at it from different angles. Having done so, they must be able to apply what they already know to the particular demands of the problem itslef. This ability is related to the flexibility which was mentioned earlier. It also runs somewhat counter to the way in which much research is done and rewarded at the present time. Generally, one can expect to succeed more rapidly and completely by mining out single veins than by doing wide prospecting. Interdisciplinary research puts a premium on being able to use one's pick and shovel on new veins of ore, which may be discovered in rapid succession. The ability to do this may differ considerably from the ability of many specialists to succeed in their narrow fields.

If possible, each person on the team should contribute different attitudes toward the project. It is important that the team be balanced in its perspective. It will be useful if some members are very optimistic about success and others are much more tenative. If everyone is prepared to rush headlong, falls may result. A balance of restraining influences may be useful. There should be persons on hand to "keep the team honest" about what it is really accomplishing, whether the results obtained will really stand up to scrutiny, and so on. At the same time, there must be visionary spirits, willing to take risks and plunge forward into what may be unknown territory. The virtue of a team is in part that it can keep these different attitudes unmixed by drawing them from different individuals. Rather than having an individual who must keep these warring attitudes in harmony within a single person, we can keep the polar opposites fresh and uncompromised in separate people, always ready to be brought out and used when they are needed.

The last two characteristics are necessray in good researchers under any circumstances and are characteristics about which whole books have been written. The persons on the team should be filled with curiosity, and they should be able to ask good questions.

In the context of interdisciplinary team research, curiosity implies a special desire to know about things outside one's discipline ("I have always wondered what anthropoligist really are up to; now is my chance to find out"). Within undefined limits, we would perscribe almost catholic tastes. Teams will function best where the members are eager to hear what others have to contribute and then to stimulate these contributions by constant attention and feedback. Scientists, especially, thrive in environments where others care about what they are doing. A researcher's studies are often so obscure that the only persons who really care about them are either graduate students trying to get their Ph.D's, or else persons on the other side of the world. To find a fresh and willing ear may bring out the best in nearly any researcher.

On an interdisciplinary team, the ability to ask good questions is nearly at the heart of communication. The purpose of the team is to get the different disciplines in focus on the same problem at the same time and to apply their efforts in a unifed way.

Mutual questioning is important to this process. Sociologists should be able to raise good questions or biologists to answer; engineers should what the curiosity of physicians with their questions about how to deliver health care. In the long run (perhaps beyond the scope of a single project), good questions are probably more important to the progress of science than are the temporary answers produced for them. We think this will be the case in interdisciplinary team research, too.

Motivation for Interdisciplinary Research. This motivation needs to be explored before a person is selected for the team since motivation must be high, or else the problems connected with both team and interdisciplinary research will overwhelm the individuals on the team.

There are two negative features to avoid. Persons who have a closed theoretical framework, or who have a great deal of ego invested in their profession (and the role they play in consequence of it), should not be part of interdisciplinary teams. Those with a closed frame of reference will find it very difficult to relate to the others on the team and will probably become disruptive influences. Persons whose egos are invested in their own professions will find it difficult to be open with others about their own limitations and those of their disciplines; they will also find it hard to change roles smoothly when it becomes necessary for them to learn from the others on the team. For such persons, the whole idea of interdisciplinary research may be a threatening one.

On the positive side, there are a number of motivations which are important in a team member. The first may be a felt need for collaboration. The individual may be one who just enjoys having a partner (or partners) in research, who likes other people around. In the face of an interdisciplinary problem, it would be a person who recognizes the need to have people from related disciplines involved in the solution of the problem. Whatever the source of the motivation, it is important that the motvation exists.

It will be useful if the team members have a special interest in problems which cross disciplinary lines. Most scientists, as we have suggested, probably are interested in problems — often very narrow ones — within their own disciplines. For interdisciplinary research the interest should ideally be quite different; broad problems which require cross-disciplinary effort should be perferred by team members. This may be a difficult criterion to fulfill but will be helpful to the team effort. Even if not all the team members come with this motivation, there should be enough on board so that they will reach out to the others.

If possible, the team members should have an active dissatisfaction with the limitations of their own disciplines. This also may not be easy to find but will be helpful. Such persons are aware of the shortcomings of their disciplines and would like to do something to overcome them. Because they are strongly motivated to reach out to others across the boundaries of their disciplines, they are particularly suited for interdisciplinary team research. It will be especially helpful if they are aware of limitations in detail, can pinpoint them, and have ideas about how to overcome them. We are not suggesting they come with axes to grind, merely that they have a positive attitude toward overcoming the limitations they see.

Persons coming to the team should be motivated to offer their best efforts, as part of a team (where credit will necessarily be shared), and to the particular project which is to be done. The latter implies that they should be given a fairly complete idea of what the project is all about and where it is hoped it will lead.

Finally, one of the motivations of the team members should be a kind of community of interests with the other team members. We suggested at the very outset that, if possible, one should use a preexisting team which already has shared interests and experience. If this is not possible, it would at least be a good idea to assemble a group which has interests in common.

The Project Leader

The project leader and the project administrator need not be (and perhaps ought not to be) the same person. This is a decision which circumstnaces are likely to dictate, but it is worthwhile suggesting that the two functions can be separated. By "leader" we mean the person who leads the actual research process and provides the direction of the project as a whole. The administrator, on the other hand, would be the one to handle administrative details such as logistics and supply, personnel records, and so on. In particular, a project leader with an administrative assistant seems a good arrangement. The project leader should be free to devote this or her time to the actual direction of the project and be rather free to detail chasing.

Whether the project leader should be the chief investigator on the project is not clear. In many cases, it is not necessary and may, in fact, impede the project if the two functions are combined. The two functions might well be kept separate.

There a number of characteristics that a project leader should possess. Ideally, a project director would be a good candidate for team membership and a good project leader as well.

First, the leader should be orderly. He or she should be happy as a coordinator, insuring that things take place in an orderly way, perhaps even to the point of being compulsive about it. Someone has to worry about schedules, about priorities, about getting things done and loose ends tied up. The project leader should be the one to do this. (We are not referring to detail chasing but rather to the major job of coordinating the efforts of the various parts of the team.)

The director should direct, should be willing and able to direct (maybe even enjoy it, though many scientists do not), and as the director, should not represent any one discipline (particularly his or her own). People outside of the research community should be aware that researchers are often not interested in being directors because of the time that it takes away from their research. So in selecting a project director it is important to find a scientist who does want to direct and who evidences some ability at it. Eminence and achievement in research are not a guarantee of this interest and ability, although it may be if the worker in question has done the work on group projects and has directed the groups. Decision makers will have their own ways of recognizing someone able to do what they themselves do. Obviously, a track record would be helpful, if it exists.

Because the director will not be conversant with what each team member is actually doing, much of the coordination will have to be done through schedules which require products. The director may not be able to tell whether progress is being made until the products are produced. In such a situation, it is important for the director to create schedules and get the team to agree to them. Research efforts are notorious for being able to keep schedules. Since we are concerned here with the application of research to particular problems, schedule will be important. So it is important to have a director who can keep things fairly well on track. A record of timely performance in the past would be a good indicator of such a person. Getting the team to agree to schedules is an art in itself. Finding someone who can do that is not a simple exercise.

The director should be able to get a decision process established and should be able to ensure that when decisions are made, they are carried out. At least in part, the decision process should involve the group as a whole. Where groups are involved in decision making, there are special problems. Where the group is made up of scientists, the problems are, if anything, more difficult. The project leader needs to get the decision process accepted or established and defined, if it is not a given. Then the process has to be made to work. Finally, when the decisions are made, the leader has to ensure that they are carried out.

In connection with this decision process, the leader must be the one who enforces whatever group discipline there is to be. Scientists are not usually interested in "discipline" in any formal sense; they do not like petty rules and regulations. We are not talking about such insignificant matters. It has been said, however, that in group efforts, "Someone has to spank those who need spanking." This is the director's or leader's job. When someone is obviously interfering with the group's work and for no good reason, the leader has to bring that person back on board. This is a touchy process. The project leader must be one who can do it and who is willing to do it.

Many are prepared to argue that these administrative abilities are far more important in a project leader than the substantive knowledge a scientist has of his or her own or other disciplines. Except as the latter may affect the status accorded the project leader, we generally agree. The project leader needs to be a leader first and a scientist second. Whether other scientists will respect anyone but an established scientist in that role, we are not sure. However, they will probably not respect even a distinguished scientist who is shown to be inept in a leadership role.

Ideally, the project leader would be a person with wide experience in collaborative work and with some knowledge of all the disciplines to be involved in the project. This may be asking for a great deal, but it is at least a direction in which one should look. Track record would be helpful at this point, although more than just a curriculum vitae should be examined to discover the track record.

In summary, there are special kinds of scientists, able in their own fields, who also have a desire and interest in interdisciplinary work and an ability (hopefully a proven ability) to be team leaders and project directors. This should be a relatively but highly desirable combination.

It is unlikely that one an learn how to be a good administrator or team leader in a short time. Thus, whenever possible, it is important to select suitable persons rather than trying to train them for their work. On the other hand, persons with the requisite abilities and sensitivities might be able to become good administrators and leaders durng the course of a project. This latter approach may be taken in many cases.

The Hiring Process

Hiring team members on a full-time basis is not the only way to arrange for their service and may not even be the best way. It has been sugested that members of an interdisciplinary team should not devote their full time to the interdisciplinary research project. This is because taking full-time away from their disciplines will be harmful to the careers. Also, as specialists in a discipline, the must keep up with new developments, and this can only be done by continuing their regular work.

The proportion of their time which might be devoted to an interdisciplinary project has been suggested as about half to three-quarters time. Anything less than half time is thought to be too little, because it does not permit enough contact with other team members; Anything more than three-quarters cuts off contact with the person's discipline. Some project leaders, of course, will want their staff only on a full-time basis. This is easy to understand and has advantages to the project; but it has disadvantages as well, and these should be borne in mind.

The job descriptions used in the hiring process should be based on a careful evaluation of the project's needs. They should not be a mere shopping list for disciplines. The disciplines to be involved should be carefully selected and the particular things needed from each should be outlined in reasonable detail. It is perhaps too easy during hiring to apply one's own stereotypes to the individuals from another discipline: "I need an engineer, and all engineers are like X; therefore I can hire any engineer and get X's qualities." It may be useful in producing the job descriptions to discuss them with experts from the discipline; they may be able to offer good advice on which particular kinds of training and experience will best fit the project's needs.

From each of the candidates it will be well to obtain rather full information of several kinds, which are mentioned below, together with some explanations about each one.

In any curriculum vitae, one would expect to get informaton on a candidate's training and experience. This will be important for the reasons mentioned in the previous section on selection of individuals for the team. The interdisciplinary and group research experiences of the candidates will, of course, be particularly important.

Because of the need to fit the job descriptions precisely, it is important to press questions about the individual's areas of special competence. In applying for jobs, many otherwise intelligent and able persons do not always put their best foot forward. They may not be well enough aware of the project's nature to really relate it to their own experiences and background. In either case, it is important to probe until the full picture of special experiences has been laid out. Often, a candidate will not even see his or her experiences as relevant until the questions are actually asked.

Interdisciplinary and group research experiences should be explored in depth with the candidate. Where the candidate is a probable choice, the person doing the hiring (perhaps the project leader) should probably be in touch with the people on the team or in the group with which the candidate has worked. Interdisciplinary graduate training might be particularly valuable. Its nature and quality should likewise be carefully explored. Where good results were attained by the team or group, it is important to learn the extent of the candidate's contribution. This will not always be easy to find out (one of the problems with all shared research), but conversations with several members of the team or group may produce useful information.

Finally, as we have already suggested at some length, the person hiring should look at the candidate's personality and personal characteristics very carefully. Most of these will not show up in curriculum vitae, and whether they will be mentioned in letters of recommendation will depend on the approach the letter writer takes to the task. Interviews may be the best way to get at these personal traits. We suggest that the interviews be conducted by a group of at least three persons, preferably from different disciplines, and that they extend over a period of a day or so. It is important to see how a candidate does all the things we have suggested as important for a team member. The interviews might consist of individual meetings with those involved in the interviewing process and then a group session or two. The process might be broken up by having meals together, during which the lighter side of the candidate's personality can be explored. Interviewers should bear in mind that it is not just the candidate's intelligence, ability and experience that is involved; the candidate is especially being evaluated as a member of a team.

The chemistry involved in creating a team requires that the selection of the personnel be in the hands of the people responsible for the team's work (preferably the project leader or director). The selection of team members should not be in the hands of department heads or other senior people in the various disciplines to be involved. To ask, "Send us somebody good, will you?" is a terrible mistake. It invites the creation not of a coherent team, but a committee of sorts.

Staff Retention

Multidisciplinary team research may present particular problems with regard to retaining staff.

Retention will be higher if the team members know what they are getting into from the very beginning. Once they have been selected, it will be important to obtain their wholehearted commitment to the project. This process should begin with the most thorough team project briefing that time will permit. Team members should be encouraged to ask questions, and honest answers should be given. Where they see flaws in the project design or staffing, these should be considered carefuly and responded to in an appropriate way.

If possible, these new team members might be involved in the design of the project or in other initial phases of the project which remain to be done. Every effort should be made to make them feel part of the team and part of the project from the outset If appropriate, efforts should be made to involve them socially with the rest of the team members so as to build coherence. Other ideas along these lines will occur to anyone who has led any kind of group.

It will also be appropriate at the very outset to discuss with the team what rewards they can expect as a result of the project. Publication of the results, authorship of the final report, likelihood of follow-on work (or, on the other hand, likelihood of the project's being cut off midway), and all related matters should be openly and candidly discussed. It is always important to do away with rumors, particularly so when the success of the project depends on the close cooperation of the people involved. Minimizing the time spent by the team members on idle speculation and gossip will increase their efficiency as well as help the retention problem.

It will also be wise to discuss the hazards of interdisciplinary "interlude" to a career made within a particular discipline. This is only fair to the researchers involved and will, by assuring them of the project's interest in them personally, help cement their loyalty to the project effort.

Other techniques and considerations which should be part of any effort to motivate and retain the loyalty of workers would, for the most part, apply to a multidisciplinary team project.

Team Organization

This is a very difficult subject to deal with, probably because the models for organization are so varied, and because each new research problem may require a different kind of organization for its attack. In addition, individuals vary a good deal as to the type of organization within which they work well.

Aside from the following general remarks, we will leave the operational structure of the team to be devised by the project director and the team members themselves.

Because individuals vary in their attitudes toward organization and structure of working groups, some of the team members may be unaccustomed to or even may actively dislike the organization that is developed, whatever it is. Something had best be done to reduce the tension and conflicts which may flow from such situations. Project leaders are probably the ones to identify these cases and then determine what is required to promote the best interests of the team, the project and the individual involved.

It is important to recognize that in team research the informal organization of the team is quite as important as its formal organization. A great deal of the work of the team will be done through informal meetings and discussions. The project leader should be aware of how the informal structure works and should assist its function where the project is furthered by it. To neglect to understand this informal structure can often bring as much trouble as a failure to create and maintain the formal organization of the research team.

A person's discipline should not be mistaken for his or her role on the research team. Role is determined as much by personality and personal traits as by the person's discipline, training and experience. To the extent that a person's role can be defined and made part of an organizational structure, this should be done at the start of the project. However, much of the individual team member's actual role will be defined only as the team works on the project and settles into its working patterns. In many cases a person's role will, in fact, take precedence over his or her discipline in the functioning of the team. This should not be thought of as a problem unless it is obviously hindering the teams, efforts.

As was mentioned earlier, status does influence the way in which an individual will function on a research team. We agree with the advice that the role of a staff member on the team should be consistent with that person's status. Both should, of course, be consistent with the needs of the project and the successful functioning of the team. Differences in the status of individuals on the team can cause problems and research directors should be aware of this. To minimize the friction these differences may cause, it will be best to keep roles and status consistent. On the one hand, this may mean that if a person acquires a high status within the team, he or she should receive an appropriate position on the organization chart. It also means that a distinguished scientist should not be given a minor role to play. Status as a consultant to the team might be more appropriate if not much of his or her time is really required.

Finally (and this has a good deal to do with team member retention too), the director should be aware that no two members of the team will see the project as of equal interest. Some will feel strongly motivated, others much less so. It is important in these cases to help each team member to see his or her own payoffs in the project. True, the group as a whole will feel a sense of accomplishment if the project is successful; but the individuals must each also see their own best interests, or they are less likely to give of their best. The project director needs to discuss this with the team members and then use the organization of the team as a means to couple the group's goals to those of all the individuals involved.

Physical Facilities

We are not concerned here with the particular kinds of facilities and equipment which may be needed to attack a given research problem. We wish to make only one point.

Since the project is conducted by an interdisciplinary team, it is important that provision be made for the team function of the group. We mean that provisions must be made for the team members to meet (formally and informally) and interact freely with one another. If possible, joint work space or adjoining work areas should be provided. A joint coffee room may be valuable (especially if provided with a blackboard or similar facilities). Staff from all levels should make it a point to interact with others, and the physical facilities can foster this greatly. Wherever possible, we would like to see separate and distinct work areas avoided, although we realize that some kinds of organizations may require them.

The Role of "Bridge Person"

While we have avoided discussion of the particular roles that individuals on a research team are likely to play, there is one role — that of the "bridge person" — that is so central to interdisciplinary or multidisciplinary research that it needs to be mentioned.

The bridge person is one who is involved in acting as a kind of bridge over which communication can occur between two different groups or individuals. In the context of multidisciplinary research, the bridge person facilitiates the communiction between persons from different disciplines (and sometimes the communication between the research team and those outside it, including the sponsors of the research project).

There are many situations in life in which a mismatch occurs between persons trying to communicate with one another. It is as though they were trying to speak in different languages or were using different coding systems. Differences in background, experiences, training, and perhaps mind set, philosophy and ideology, are all involved. Persons from different disciplines would be expected to be afflicted with this kind of mismatch.

There is at least some evidence to suggest that when the members of a group are trying to solve a problem, they will generally look first (and sometimes only) within the group for help. At least in part, this strategy evolves because of a mutual feeling that "only we really understand what the problem is." This suggests that bridge persons should be found among the members of the interdisciplinary team, rather than brought in from the outside.

It is likely that some individuals on the team will gradually come to play this role rather consistently. When mismatches in communication occur during discussion, these will be the persons who try to resolve them, often by acting as translators.

Some individuals naturally fill this role well and will gravitate toward playing it. Ideally, the project leader would be such a person. If he or she is not, it will be important to ensure that one or more of the other team members can perform the role.

The bridge person has an especially difficult role to play where there is a communication mismatch between the sponsors of the project and the project team. We expect that this situation probably will be rather common.

In such a case, someone is needed who can explain the team's efforts and approach to the sponsor and express the sponsor's concerns and goals to the team.

On one side, it is sometimes too easy for the research team to forget what its purpose is, and go chasing after interesting problems which cross the team's path, while they are on the hunt for the sponsor's game. On the other side, it is quite possible for the sponsor, by asking the wrong questions or specifying the acceptable kinds of answers, to make the research team's efforts of little value. The bridge person's role is to try to explain these problems to each side and to try to help the researchers and the sponsor to work together to achieve a useful and valuable result.

The project leader is probably best qualified to act as the bridge person between the team and the sponsor, but if he or she cannot function in the role, someone must be found who can.

Unless good communication is developed between the team and the sponsor early on, little of the advice offered in this paper will be of much use.

Some Suggested Reading

Because of the informal nature of this paper on the management of multidisciplinary research, we have not attempted to provide detailed references to sources, nor shall we do so here. But, as we said at the beginning of this chapter, managing multidisciplinary research is a topic that cannot be adequately treated within this small space. Therefore, some reading materials that may enable interested users of this Handbook to continue their search for useful methods and ideas are suggested below.

This chapter itself has relied heavily on a unique source — a volume which complied and synthesized the views and expreiences of 107 distinguished researchers and scholars, all participants in multidisciplinary team research. This book, which grew out of a series of work conferences held in the late 1950's was the work of Dr. Margaret B. Luszki, who used tape recordings of the discussions between conference participants as her source material. We believe this synthesis is especially important because the researchers involved were all from the social and behavorial sciences and so were likely to be especially sensitive to the various interpersonal relationships which are central to successful research of this type. The book was Interdisciplinary Team Research—Methods and Problems, published in 1958 by the National Training Laboratories of the National Education Association under a grant from the Public Health Service. Using this volume, we have attempted to generalize from the experience of these workers, combine it with our own, and make its advice more definite and prespective than those involved in the work conferences probably would wish.

Readers of this Handbook may also find useful the various writings of William J. Gordon and of George M. Price, both of whom were closely involved with the group and interdisciplinary problem solving technique called "synectics." We recommend their work not so much because we propose using the specific synectics approach as because we believe that they offer considerable insight into productive ways of using groups of workers drawn from various disciplines to help solve research and practical problems, especially ones like those which this project addreses.

Finally, in thinking about communications between interdisciplinary research team members, we also have been influenced by the work of T.J. Allen and S.I. Cohen who have examined the problem of communication in research and development groups. They, among others, have proposed the concept of the "technological gatekeeper," a concept which we believe is important to the functioning of multidisciplinary research teams.

7. CONCLUDING THOUGHTS AND OBSERVATIONS

The preceding sections of this paper have attempted to set forth as simply as possible a series of guidelines that can be used by state and local government offices in the organization and carrying out of scientific research. It is fully recognized that each state and local government will adapt its own approaches to the need for new knowledge in pressing complex areas. Undoubtedly no two states or local governments will approach their research assignments in exactly the same manner. The guides contained in this paper should be used as a checklist as state and local governments gear up to undertake scientific research.

The key actor is the translator or project director who must communicate to the scientific research team the nature of the problem and the political framework within which the issue is raised, and then communicate back to the political leaders the findings of the scientific team. This translator-communicator-interpretor function calls for a person who is comfortable in both the scientific and political policy-making worlds.

Simply, tossing a scientific policy-related problem to a university or a research institute will not work. Universities operate on a peer approbation basis, in a hierarchical fashion. Newly appointed associate professors need the approval of their peers on the disciplinary research they are undertaking in order to achieve tenure and to advance to the rank of assistant professor. The same thing can be said of the movement from assistant professor to full professor.

One Governor's science advisor, himself a well established academician and interpretor-translator in the Governor's office, made the following observations on the assembling of the research team. Ideally, he noted, this multidsciplinary research team should be made up of one or more senior professors close to retirement or emeritus status, inasmuch as these people are at the top of their professions and don't face the peer pressure to do disciplinary research and to publish. He would then couple these senior people with fresh, newly minted Ph.D.'s who have not yet entered into the pressures of the academic world.

In short, his conclusions were that it is the people who make the team work not the institutions where the people come from.

The fact is that multidisciplinary research teams must be chosen with the utmost care for all the reasons outlined in Chapter 6. What will be new to most researchers, and there is good chance that it can be an exciting experience, is the application of their research to public policy making at the executive and legislative levels.

The results of the first year's NSF State Science Engineering and Technology (SSET) study grants are beginning to come in. A recurring theme seems to be that Governors are looking to the establishment of mini-cabinets (made up of senior state officials and appointed representatives of the scientific community) to broaden the Governor's policy umbrella and policy presence. These developments are in response to the fact that governors' offices have been faced with an almost overwhelming necessity for the development of policy in new areas of concern, particularly over the last ten years. Most governors look at the utilization of Science and Technology resources in policy development as a more effective way of extending themselves over broader areas of concern.

The SSET report from the state of Oregon had this to say concerning the need for S&T capability:

> Regardless of the management style of the Governor, information and advice are a critical element in the formulation and management of policy. That information and advice ought to:
>
> Be available within the time frame of the situation at hand; Be objective and avoid advocacy of any special client or philosophy; Appreciate issues from the Governor's perspective and provide responses that are tightly focused; and Provide access to the best available resources, wherever they exist.

Rhode Island's SSET report addressed the Governor's time constraints indicating that:

> As one of four states that has a two-year term for its Governor, Rhode Island's executive office must consider and develop policy, translate that policy into legislation, and organize a host of other functions in a very short time period.
>
> Rhode Island's SSET project was designed to focus on:
>
> 1. An analysis of existing practices for the incorporation of science and technology information into Executive policy formulation;
> 2. The identification of the range and nature of the information sought;
> 3. The capabilities of both the public and private sectors to respond to both the scientific and sustaining informational requirements; and

4. The development of alternative modes of organization that could assure the effective and timely flow of information into the office of the Governor.

The State of Maine concentrated its SSET study on accessing science and technology to provide inputs into the policy-making process. The study embraced both the legislative and executive branches. They conducted extensive intrviews and developed case studies of fifteen bills introduced into the legislature during the 108th session, which included substantial science and/or technological (S&T) questions.

Their study employed a broad definition of "science" as a body of systematic knowledge incorporating the social, as well as natural, physical and engineering sciences. "Technology," they said, is the application of engineering in the design of materials, structures and processes to further practical ends. They identified some twenty-six explicit S&T issue areas facing the executive branch.

Maine summarized the use of S&T information in the Governor's office and executive branch, as follows:

> The bureaucracy serves as only a partial source of hard S&T information, as outside consulting firms are the largest contributors. This is due to the shortage of engineers and technologists in state government, especially in the area of research. Internal politics and lack of human resources necessitate the use of outside sources.
>
> The problem with the current information system is that S&T is not presented in a manner which the Governor can understand. Reports are often too lengthy and complex, and not policy oriented in their presentation. Therefore, S&T information needs to be translated into concise, easy to understand terms, which will best support the decision process.
>
> The study therefore, recommended that: "A science advisor to the Governor could perform the role of 'translator' and ensure that S&T information is properly presented in clear and concise terms. A council of Science Advisors consisting of from five to seven senior scientists was also recommended. It should meet monthly, with the science advisor funneling controversial items to it in agreement with the Governor. The advisor must deal with the more immediate, complex problems and determine research priorities. The university could also be used as a means of getting the state in touch with national experts when the state lacked the personnel resources."

Montana's SSET effort was in much the same vein. The state focused on ways to provide technical staff support to translate scientific and technological information to meet the needs of state policy makers. On the other hand, the Florida SSET program found that a review of the recently completed State Comprehensive Plan (released

February 9, 1978) indicated that forty-three percent (391) of the 919 policy recommendations in the plan had a strong relationship with science, engineering and technology, a fact that was not clearly understood at the time that the plan was prepared.

The National Science Foundation's Local Government Program has established several experimental innovation networks which aim to develop relationships between local governments and universities, Federal laboratories and other scientific and technological resources. The networks, based upon consortia of local governments in conjunction with the National Science Foundation, can aid in resolving complex problems which are faced by local governments. The networks provide a variety of models for coordinative efforts between local and state governments, universities, the nonprofit and private sectors, federal laboratories and other entities. They show great promise for effective and meaningful interchange regarding the transfer of scientific and technological information.

In August 1979, the U.S. House of Representatives Committee on Science, and Technology, Subcommittee on Science, Research and Technology completed a special oversight report entitled The Role Of Federally Funded R&D in Assisting Local Governments. The report was partially based upon hearings held during the 95th Congress by the Subcommittee on Domestic and International Scientific Planning, Analysis and Cooperation. The hearings, which were entitled "The Role of R&D in Improving the Quality of Urban Life," addressed the existing and potential federal role in improving the innovative capacity of local governments. The report presented some important conclusions and recommendations emphasize a growing current federal concern and involvement in this area. The report developed the following major conclusions:

- Increased productivity and improved managerial performance by local government is a necessity in the face of increasing demands for municipal services without the willingness to pay for such services.
- Local government officials at the hearings voiced a desire to utilize scientific and technological resources to increase the productivity of their organizations.
- The current system of science and technology sharing among various levels of government is not adequate.
- There is great potential for improved productivity through the expansion of science and technology transfer programs.

In the report, a number of recommendations were presented which addressed these conclusions. In brief, these recommendations call for:

1. An increase in the federal investment in R&D directed toward resolving urban problems (in the range of an additional or redirected $20 to $50 million annually);

2. An urban research agenda which is equally responsive to both federal and local needs through improved problem-solving capability at the local level, and improved planning and program evaluation at the national level;

3. Intergovernmental and interagency coordination in the development and implementation of the local research agenda;

4. Action to coordinate the identification, creation, dissemination and utilization of local R&D through:

   - An ongoing national commitment to local government networks;

   - An assessment and selection of priority local government needs to be used in determining appropriate research agendas for federal agencies;

   - The allocation of additional funds to support ongoing efforts for interagency coordination;

   - The utilization and involvement of federal laboratories, local government public interest groups and the private sector;

   - The development of an informational exchange system to augment capabilities and communications;

   - The periodic evaluation of urban technology transfer projects for use in future funding decisions; and

5. Further investigation of the existing and potential roles for universities and the federal laboratories in creating and providing technical knowledge useful for solving local public problems.

These recommendations generally underline and support the materials provided in this Handbook. This timely reiteration of objectives and findings by a committee of the U. S. Congress is an indication of a promising commitment on the part of the federal government to achieve coordination with and provide assistance for municipalities.

All participants in these developments are the first to admit that there is a long way to go in:

- Communication between the actors;

- Understanding problem solving;
- Assessing problems in terms of the potential contributions science and technology can make to public decision making and policy making; and
- Development of meaningful and constructive, interactive dialogue and understanding between political decision makers and the scientific communities of the country.

However, the congressional, federal agency, state and local efforts which have been described show that great headway is being made in augmenting governmental capabilities at all levels in the application of scientific and technological resources to policy development and public decision making.