Follow-up

TF Memo

October 7, 1966

EYES ONLY

MEMORANDUM TO

Honorable Donald F. Hornig
Director
Office of Science and Technology

This memorandum establishes under your chairmanship a Task Force to evaluate the alternative methods for conducting studies of natural resource policy, energy resources, and subsurface excavation technology. This Task Force should include representatives from the Department of the Interior, the Council of Economic Advisers, and the Bureau of the Budget, and may be broadened at your discretion. You are encouraged to consult representatives from other interested agencies where appropriate.

May I suggest that you discuss with the heads of these agencies individuals to represent them on the Task Force. As you know, we should have the finest possible talent on the Task Force.

We would like you to evaluate the need for and alternative methods of conducting separate studies in the following areas:

(1) A study of existing Federal policies for the development, use, and conservation of minerals, metals, and related resources, alternatives to existing policies, and, if new policies are called for, legislative and non-legislative changes which ought to be made.

(2) A study of existing Federal policies for the development, use, and conservation of the Nation's energy resources, alternatives to existing policies, issues in the energy field requiring attention, and, if new policies are called for, legislative and non-legislative changes including organizational changes, which ought to be made.

(3) A study of the state of underground excavation technology; efforts being made publicly and privately to develop the technology; the need for a unified and intensive research and development effort; and, if an intensive research and development effort is called for, the ways in which such an effort might be made.

As you are aware, several alternative methods for conducting such studies are available. Among others, consideration should be given to the following: A Presidential Task Force composed of persons outside the Government with authority to engage consultants as needed; the National Academy of Engineering; the National Academy of Sciences; a contractual arrangement whereby the study would be conducted by a private agency or organization. This list is suggestive only and you are encouraged to consider all available alternatives.

We would like you to submit by November 15, 1966 a detailed report containing your conclusions and recommendations, as well as the alternatives rejected and the reasons therefor.

Ten copies of the report should be submitted to me and five copies to the Director of the Budget.

Joseph A. Califano, Jr.
Special Assistant to the President

cc:
Budget
CEA
Interior

BoB Analysis

B.B. FORM NO. 34

UNITED STATES GOVERNMENT

Executive Office of the President
Bureau of the Budget

Memorandum

TO : The Director

DATE: December 1, 1966

E. F. Shepard

FROM : Resources and Civil Works Division (E. Fenton Shepard)

SUBJECT: Report of the Task Force on Natural Resources Studies

This task force report deals with the need for and methods of conducting studies of non-fuel minerals (copper, aluminum, lead, zinc, etc.), energy resources, and excavation technology. The report recommends that steps be taken to initiate analytical studies in the non-fuel minerals and energy areas, and that an expanded program of research on tunneling technology be instituted with a first-year effort of $4.6 million.

Non-fuel minerals study

The task force report concludes that, while there is not a pressing need for a study aimed at finding short-term remedies, there is need for a careful analytical appraisal of the technological and economic changes taking place in the industry as a basis for evaluation and development of governmental policies and programs affecting the non-fuel minerals industry. To accomplish this objective, the report recommends that arrangements be made with a nonprofit organization such as Resources for the Future for preparation of a detailed prospectus for a study of the non-fuel minerals industry. On the assumption that review of the prospectus would lead to a recommendation to proceed with the study, the task force recommends that provision be made in the 1968 budget for the Department of the Interior to finance the study, at a cost of $500,000.

The American Metals Climax Company has pressed the White House for a broad commission-type study of the minerals area similar to the Paley Commission which reported in 1952. The task force recommendation is, in part, an effort to meet this pressure without endorsing a full-scale Paley-type Commission study.

We concur in the desirability of having a study to provide a better understanding within and outside Government of the changing economic and technological developments affecting non-fuel minerals. The early successes of the heavy metals program confirm the possibility of further technological developments in the minerals field. At the same time, we recognize that it will be difficult to achieve improved governmental policies and programs in this area, and that as a result of the study, there may be pressure for adoption of additional subsidies for the domestic minerals industry. Despite this danger, staff believe it would be desirable to proceed with the prospectus for this study and to finance the study in the 1968 budget if overall budget constraints permit.

Among the issues involved in this area are such matters as tax depletion allowances, mining and other public land law provisions, import regulation, and the level of Government research and assistance for exploration and development. The Public Land Law Review Commission is also involved in many of the policy issues which affect the non-fuel minerals industry.

Energy resources study

The task force report enumerates a number of specific energy problems in such fields as public land policy, trade policy, taxation, and regulatory activities, and presents a convincing case of the need for a comprehensive framework in terms of which to consider specific energy problems and policies. The task force, therefore, recommends establishment in the Executive Office of the President of a small energy policy staff on a permanent basis to provide a coordinated approach to the resolution of energy policy issues. It also recommends that a contract be made with a nonprofit organization to design a study to develop energy goals and policy objectives and to provide a framework to guide consideration of specific energy issues. As in the case of the non-fuel minerals study, the task force recommends that it be retained to review the study design and to make recommendations for the conduct of the study. A Presidential commission on national energy policies is to be considered only if the comprehensive study develops specific policy approaches that warrant public examination and discussion, and executive and congressional action.

Because of the complex questions involved in determining desirable location of a permanent energy policy staff, the task force recommends that the Bureau of the Budget be requested to conduct a study and make recommendations to the President on the most appropriate organizational arrangements for locating an energy policy staff in the Executive Office of the President.

Bureau staff have long recognized the need for more objective consideration and better coordination of energy policies. No appropriate means have been found to achieve more adequate and objective leadership within the departments and agencies now handling energy policies and programs. At the same time, the strategic importance of Government policies in this area and the impact of piece-meal actions on the energy industries have made it difficult to achieve needed overall improvements which take into account interactions among competing energy resources. We concur, therefore, in the desirability of establishing a permanent central energy policy staff and the development of an overall framework study.

While the task force favors the establishment of a central staff within the Executive Office of the President, the Office of Management and Organization indicates that if the Bureau is requested to make the organizational study recommended by the task force, the Bureau study should not foreclose full consideration of the desirability of locating such a special staff either within or outside the Executive Office of the President.

The task force did not make a specific recommendation on the financing of the proposed framework study. However, the task force assumed that the study could be financed by interagency contributions. Such a study might cost more than the non-fuel minerals study, and budget policy for 1968 may make difficult financing by reprograming in 1968. Another alternative would be single-agency financing by an amendment to the 1968 budget for the Department of the Interior with provision made for this item in the allowance for contingencies. An amendment or supplemental would be forwarded after the prospectus for the study has been prepared and appraised.

The task force report makes reference to a natural gas survey being proposed by the Federal Power Commission for initiation in the fiscal year 1968, and indicates that the terms of reference for any Federal Power Commission study should be reviewed in relation to the energy resources study proposed by the task force. The question of proceeding with the Federal Power Commission natural gas survey is discussed in a separate memorandum from the Division.

Tunneling technology

The task force report summarizes the principal areas in which improved tunneling technology may have application in future years, the status of ongoing research and demonstration programs, and the possibilities for technological development in this area. The report concludes that, because of the possibilities for improved technology, a Government-wide program should be established to advance tunneling technology, with a first-year program emphasizing state-of-the-arts studies, assessment of alternative concepts, requirements studies, and advanced systems development. The first-year financing of $4.6 million would be through the Department of the Interior (Bureau of Mines and Geological Survey), the Department of Transportation, and the Department of Housing and Urban Development.

The report also recommends establishment of an interagency planning committee, including OST, Commerce, Transportation, Interior, Department of Defense, and possibly AEC (HUD is not mentioned but should be included). Initial program leadership is to be provided by OST.

The possibilities for cost reduction through improved tunneling technology are probably very great over the long run. However, it is by no means certain that improved technology can be developed quickly. The task force report envisages a 10-year program with relatively large expenditures in later years. It seems clear, therefore, that the payoff from improved tunneling technology will come in later years and will not materially change near-term expenditures for various tunneling requirements. Viewed from this perspective, an expanded research program does not appear to have high priority for 1968 compared with other essential programs and large military expenditures.

There are additional questions which will need to be resolved before final decisions are reached on the financing of a first-year expanded research program. One is the question of central financing through the Bureau of Mines with transfer of funds to other agencies involved or multiple-agency financing such as envisaged in the task force report. The adequacy of

Interior's legal authority for central financing by Interior is being explored with the Department.

The Bureau of Mines has included only $100,000 for a preliminary exploratory study in its 1968 budget request. Therefore, to finance a much larger program will require an add-on to the 1968 Bureau of Mines' request. On the other hand, general budget policy may require starting this program at a slower rate than proposed by the task force.

Summary

T F Report

THE WHITE HOUSE
WASHINGTON

Wednesday, November 23, 1966

4:00 p.m.

Under Secretary Boyd
Charlie Zwick
Under Secretary Wood
Art Okun
Don Hornig
Director Schultze
Jim Gaither

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY
WASHINGTON, D.C. 20506

November 23, 1966

MEMORANDUM FOR

Joseph A. Califano, Jr.

Subject: Natural Resources Studies

This is in response to your memorandum of October 7, 1966, establishing a Task Force to evaluate the need for and alternative methods of conducting studies of (a) Federal policies for the development, use, and conservation of minerals, (b) Federal policies for the development, use, and conservation of the nation's energy resources, and (c) the state of rapid excavation technology.

The Task Force, which I chaired, included Gardner Ackley (CEA), John O'Leary and Walter Hibbard (Interior), Carl Schwartz (BoB), and Lee White (FPC). Its report on each of these study areas is transmitted herewith.

The Task Force has concluded that there is need for broadly based studies in both the non-fuel minerals and energy resource areas to guide government policy formulation with respect to these sectors.

In the case of non-fuel minerals, the study should aim at developing a better understanding of the effects of technological change on the economics and incentives of the industry and of the ways in which governmental policies can strengthen the contribution of the industry to national objectives.

A study of energy resources is needed to guide governmental actions with respect to a number of energy resource issues that bear on the responsibilities of several Federal agencies. Since the various energy resources are to a large degree interchangeable, there is need for a penetrating assessment of the objectives of national energy policies and of the effects of alternative policies on the real costs of energy to our society.

However, with respect to the energy question, the Task Force accords highest importance to the creation of a small, senior energy policy staff in the Executive Office of the President to undertake and coordinate analytical studies of energy policy issues and to take the initiative in bringing appropriate recommendations for their resolution to the President for decision.

Before proceeding with the conduct of studies of non-fuel mineral and energy resources, the Task Force recommends as a first step the preparation of a study design or prospectus for each of the studies. We further recommend that the study designs be developed through contracts with private institutions having special competence and experience in the minerals and energy fields, such as Resources for the Future and the Brookings Institution. This will assure that the necessary expertise and objectivity will be brought to bear.

Also enclosed is the Task Force report on tunneling technology which is based on a detailed study by a specially constituted sub-panel involving participation by the several interested agencies. The Task Force agrees that tunneling needs of the nation can be expected to grow rapidly and that an accelerated Federal program of research, development, and of systems engineering and feasibility studies is justified until the scale and character of future tunneling markets become sufficiently established to stimulate private investment. This will require $4.6 million the first year and larger sums thereafter.

Don

Donald F. Hornig
Director

Enclosures

NON-FUEL MINERALS STUDY

Problem

Both the production and the uses of non-fuel minerals have been undergoing profound changes in recent years. The heavy demands of rapidly expanding U. S. and world economies are tending to exhaust the more accessible and high-grade deposits of many minerals. However, recent and prospective changes in technology and in the structure of using industries may sharply alter--in either direction--past trends in the demands for particular minerals. At the same time, new technologies of ore-finding, mining, and recovery may in some cases radically change prospective supply availabilities. New directions of public policy (e.g., as concerns air pollution, or the development of backward countries) could strongly affect supplies or demands for some minerals.

The ability of the industry to respond to national needs in this new environment is and will be affected by its industrial structure. Its several segments vary considerably with respect to such aspects as the prevailing size of firms, their sources of capital, and their marketing methods. These factors have important implications for their past and future market performance.

In general, the sharply increasing pace of change in conditions both of supply and demand have created increasing opportunities for the misdirection of private investment. At the same time, the increasing cost and sophistication of exploration and development have tended to increase considerably the period over which advance planning of exploratory and productive activities is required, and often greatly to increase the necessary scale of individual investments. Particularly in light of the relatively small scale of many minerals firms, these factors may have contributed to a general tendency toward inadequate investment in the timely development of new resources, of new technologies, and large-scale integrated operations. They may also have contributed to an increasing tendency to shift to the development of overseas resources, with implications for the U. S. balance of payments, national security, and foreign policy.

The efficient response to this new environment on the part of mining and processing firms--and of the industries using their products--could be greatly enhanced by fuller knowledge and understanding of recent and prospective changes in supply and demand factors. Moreover, the ability of the minerals industries to respond efficiently to the changing environment could be enhanced by possible changes in their structure, induced by conceivable alterations in tax, public land, antitrust, and other policies. Fuller knowledge and understanding of the structure and prospects of the minerals industries could also contribute to the framing of more intelligent and effective government policies affecting production, prices, imports, research and development, stockpiles, and many other aspects of these industries.

The most recent comprehensive study of these and related problems was that completed by the President's Materials Policy Commission in June 1952. Changes since that date have made many of the earlier findings obsolete. Although much current detailed information exists on many of these problems, it has not been assembled and evaluated. Nor have the more crucial gaps in our knowledge been identified, and efforts begun to repair them. In short, there has not been a systematic and comprehensive analysis of the problems of non-fuel minerals. The Task Force believes that a need exists for such an analysis in order to advance the economic, security, and foreign policy interests of the nation.

Conclusions

The technological and economic problems that limit the ability of the non-fuel minerals industries to meet efficiently the nation's needs are long-standing and chronic. From this standpoint, there is not a pressing need for a study aimed at finding short-term remedies.

Rather, there is need to begin a careful analytical appraisal of these problems:

a. to promote a comprehensive understanding within and outside of government of the nature of the technological and economic changes taking place in the industry and in the market for the industry's products, both past and prospective, and the probable effect of these changes on the industry's ability to meet the nation's needs;

b. to evaluate the relationships between the incentives for and the level of exploration, research, development, and technological innovation needed to meet the need for increased production of resources, products, and services; and

c. to provide a basis for the evaluation and development of governmental policies and programs for increasing the contributions of the industry to the national economy; to examine but not to recommend policy alternatives.

Recommendations

a. That a contract be entered into with a non-profit organization having competence in economics and experience in the minerals field (Resources for the Future) to prepare a detailed prospectus for a study of the non-fuel minerals industry that would provide a statement of goals and a basis for evaluation and development of governmental policies and programs. The attached list of questions will serve as a guide for discussion with the prospective contractor (Attachment A).

b. That this Task Force be retained to guide the selection of the contractor, to receive the study design, and to recommend, on the basis of that design, the advisability of a study in depth.

c. That the newly formed Committee on Mineral Science and Technology of the National Academy of Sciences-National Research Council be called upon to advise and assist the contractor, as needed. Although the economic questions are dominant, they cannot be treated without full understanding of the impact and implications of technological change in the industry, of the potential for technological advance, and of the resource potential itself.

d. That provision be made in the FY 1968 budget of the Department of the Interior for the conduct of the full study which, as envisaged, will cost approximately $500,000.

ATTACHMENT A

Study of the Non-Fuel Minerals Industry in Relation to Governmental Policies and Programs

Study Objectives

1. To promote a comprehensive understanding within and outside of government of the nature of the technological and economic changes taking place in the industry, both past and prospective, and the probable effect of these changes on the industry's ability to meet the nation's non-fuel minerals needs most effectively.

2. To evaluate the relationships between the incentives for and the level of exploration, research, development, and technological innovation needed to meet the need for increased production of resources, products, and services.

3. To provide a basis for the evaluation and development of governmental policies and programs for increasing the contributions of the industry to the national economy; to examine but not to recommend policy alternatives.

General Questions

1. What are the principal technological and economic problems of non-fuel minerals resources industries that threaten to keep them from meeting the demands of growing U. S. and world economies?

2. How has the structure of the mining industry affected the nature and level of its ore-finding and other technological development? The following subjects are relevant to this question:

   - the nature and size of firms in the industry;

   - its reliance on others (i. e., equipment manufacturers, consumers, and the government) for research;

   - the long lead time involved in the development of a mine;

   - the effect of these and other factors on the industry's capacity to respond to rapid change in demand.

3. What has been the relationship between the incentives for and the level of exploration, research, development, and technological improvements and investment in the non-fuel minerals resources areas?

    - What have been the relationships between price, profits, market instability, foreign and domestic competition, government incentive programs, etc., and the level of exploration, research, development, technological improvements, and investment?

4. What have been the effects of governmental policies and programs on exploration, research, development, and technological improvement in the non-fuel minerals resources areas? These policies and programs include:

    - Federal and State mining laws;
    - property tax laws;
    - stockpile programs;
    - Federal and State tax laws, including depletion allowances;
    - import duties and quotas, U. S. and foreign;
    - beautification program and its impact on strip mining;
    - water pollution programs;
    - antitrust program;
    - public land policy.

    What are the anticipated effects of alternative policies and programs on each of these areas?

5. What have been the economic consequences of these various influences (i.e., 2 - 4) on our non-fuel minerals resources industries? The consequences to be considered would include:

    - the ability (or inability) to meet expanded requirements;
    - the stock of proven reserves to support new mining operations;

- the location of exploration and new mine development;

- shift to alternative raw materials;

- the profitability of these industries relative to other industries.

6. What are the manpower requirements of an expanding production of non-fuel minerals? What is the present and prospective supply of trained manpower available to the non-fuel minerals industries? Is there an adequate university base for the training of technical personnel for technological change in the mining industry?

7. What has been the impact of technological developments in the use of non-fuel minerals products on the demand for these products during the past 20 years? What is this impact likely to be during the next 5 years? 15 years? 25 years? What are the prospects for technological advance in ore-finding, mining, and processing?

8. What are the prospects for improvement in the economics and technology of recycling and what would be its effects on the industry?

9. In what ways are existing Federal and private programs deficient in providing the information needed for a continuing review of our non-fuel mineral resources? What changes in these programs are needed to make them more useful for decisions on exploration, research, development, and technological improvement plans, and for Federal policies affecting non-fuel minerals?

10. What would be the benefits and costs of significantly increased Federal efforts in the development of new ore-finding and deep mining technology and of alternative means for expanding the level of exploratory and mine development activity in the United States?

<u>Specific Issues</u>

1. Are limitations in the current reserve base indicative of a critically serious situation in the long-run domestic supply of non-fuel minerals, and what are the implications for the prices of mineral commodities?

   - Recent intensive effort by the Federal Government (GSA) to determine opportunities for expansion in copper supplies indicates that there is only one significant property in the U. S.--where production is not now planned--that could enter production within the coming five years.

2. In addition to any direct increased costs represented by higher prices for mineral commodities per se, is the economy forced to make substantial investment in substitution technology which would be unnecessary if long-term availabilities were more assured and prices were lower?

   - Copper consumers have made substantial research and retooling investments because of long-term price and availabilities outlook for copper. Would these investments have been justified if supply outlook were more favorable?

3. Will the end of the Colonial Era and the creation of new national states directly influence commodity supplies and prices?

   - A generation ago governments of less developed producing countries were a negligible factor in determining investment decisions, and prices of mineral commodities. In recent years we have seen the development of an organization of petroleum exporting countries, motivated by the desire to influence realized prices; the development of an International Tin Agreement which is influencing tin prices by inventory management and by export controls; the direct intervention of the Chilean government to influence the world market price for copper; and actions by lead and zinc producing countries which have affected prices for these commodities.

4. Are differences in fiscal treatment accorded extractive industries as between the U. S. and other mineral producing areas significant in influencing investment decisions of the mining industry?

   - The marked contrast in exploratory and development activity in Northwestern Canada and in Alaska, a single geologic province, indicates that differences in fiscal treatment may be significant where factors such as geology and remoteness from markets are similar.

5. Does the statutory and regulatory framework within which the U. S. minerals industry operates inhibit its ability to take advantage of the

economics of scale, and thus reduce its ability to compete effectively in the over-all raw materials context?

- The firms within the non-fuel industries are, with few exceptions, relatively small, and, as a result, financially incapable of exploiting the full range of technology available to the industry. Research expenditures are minor in contrast to other industries operating in fields with heavy reliance on science and technology. Combinations within the industry, even among smaller firms, have been discouraged by antitrust laws.

6. Do the Mining and Mineral Leasing Acts obstruct the rationalization of extractive industry?

   - Spokesmen for the U. S. mining industry have made representations to the effect that the current statutory and regulatory framework applicable to extractive operations is a positive obstacle to the application of geophysical and geochemical ore-finding techniques, and for the exploitation of massive, low-grade deposits.

7. (Question for an engineering or scientific group.)

   Would a significant increase in Federal expenditures aimed at the development of sub-surface ore-finding technology and deep mining technology have sufficient probability of success and sufficient probability of pay-out to justify its support?

   - Mining activity in the U. S. has been largely confined to depths of less than 1,000 feet, and has been essentially based upon surface evidence of mineral deposits. There is substantial geologic evidence that the occurrence of sub-surface deposits is no less frequent than those having surface indications. If this premise is correct, a major Federal initiative in sub-surface ore-finding technology and deep extractive technology could open the way to an entirely new generation of mining and could thus have major implications for meeting the mounting requirements for the future.

ENERGY RESOURCES STUDY

Problem

Over the years a number of issues have confronted the Federal agencies involving the development, use, or conservation of the nation's energy resources. The issues have been raised in the context of specific problems facing individual agencies. Although the various governmental energy policies are interrelated in their effects, there is no provision within the government for considering these policies within a comprehensive framework. Yet their ramifications bear on the responsibilities of a number of Federal agencies and cut across the diverse interests of the domestic energy industries.

The resources used to produce energy are competitive, in that one resource may be substituted more or less for another in nearly all but the transportation market. Thus, positive Federal action to advance one source of energy may have a negative effect on others.

This, then, is the crux of the problem facing the government in dealing with energy questions: how to resolve particular policy issues in a way that meets the nation's needs for energy, taking fully into consideration the interchangeability of the basic energy resources--coal, oil, natural gas, water power and nuclear power.

Some of the specific energy problems confronting the Federal agencies include:

public land policy	- timing and magnitude of Federal offshore petroleum lease sales; relationships with states with regard to conservation and proration policy in Federal offshore and onshore petroleum leasing operations; timing, rate, and procedure for disposal of Federal oil shale holdings;
trade policy	- with respect to energy trade relationships with Canada and the oil and gas import control program; development of an effective coal export program;
regulatory activities	- field price regulation by FPC; interaction between policies of FPC and other Federal agencies with energy responsibilities;

taxation	- tax treatment of energy industries with regard to resource development, conservation and inter-fuel competition; and in relation to State and foreign taxation;
pollution	- development of policies and economic procedures which will permit minimization of pollution by-products while at the same time offsetting adverse regional and international impacts arising from shifts in fuel sources required to meet anti-pollution standards;
non-energy uses	- examination of the non-energy uses of energy resources and their effects on the energy resources outlook (e.g., petrochemicals, lubricants, metallurgical coal exports);
transportation	- FPC decisions with regard to interstate transmission of natural gas; promulgation of safety standards for pipelines; transportation rate-making and systems integration and innovation which influence inter-fuel competition;
research development	- the recommendation of the Energy Study Group on R&D resources will need to be reviewed from time to time to keep them in optimum relation to the actual progress of science and technology;
social welfare	- problems related to trade-offs between alternative welfare programs and direct economic stimulus for specific energy producing areas, e.g., the anthracite producing region.

It is clear that policies affecting any one of the energy resources will inevitably produce important consequences for the others. For example, consideration of how to meet the continued growth in demand for liquid and gaseous fuels touches several broad policy fields, including national security, foreign trade, research and development, and regulatory practice. National security could be affected because lower costs of production abroad have led to sizeable imports of crude oil and oil products into the United States. A policy of import restriction must be considered in relation to other foreign policy objectives of the United States, since it affects the interests of developing nations that are dependent on their export trade in oil, and results in higher energy costs to the American consumer.

Both the number and the complexity of the energy issues have been increasing along with increases in demand, technological advances, and increased international involvements on the part of industry as well as government. Yet the ability of the government to deal effectively with these issues has not been commensurate with the need--leading to delayed action or inaction on individual issues and to inability to develop constructive policies and actions that could better serve the nation's economy and international goals.

Despite the apparent abundance of the nation's energy resources, steps must be taken as promptly as possible to correct these two deficiencies. Government policies and actions on energy resources can have long-term effects on the costs of energy in our economy (including the costs of environmental pollution), on the conservation and development of national energy resources, on national security, on foreign policy objectives, and on international trade. On the one hand, the abundance and interrelatedness of energy resources provides the opportunity to develop a long-range energy strategy that can serve the many national interests involved. On the other hand, decisions on specific energy issues taken in a narrow energy context can seriously impair or even foreclose later opportunity to exploit energy resources to the maximum national advantage.

The essential need to deal with the specific energy issues in a comprehensive framework of energy considerations has been repeated in a series of Presidential-level reports, ranging from the President's Materials Policy Commission in 1952 to the Presidential Task Force on Natural Resources in 1964. The question is not whether to move in this direction, but how.

The first step is to develop a broad, coherent framework of understanding of the national energy resources supply and demand outlook, of the sensitive interrelationships among energy resources and of possible consequences of alternative government policies to guide decision-making with respect to particular energy resource problems.

We do not now have such a broad framework of understanding, nor do we clearly perceive its dimensions and make-up. This has led the Task Force to conclude that there should first be an appraisal of the best approach or method for systematic research and analysis and that arrangements should be made with a non-profit institution with competence in the field of energy resources for the development of a careful statement of the entire problem and of a feasible research design or work plan. Attached is a statement of some of the problems and issues that should be considered in designing the study, which may be revised or elaborated with the institution selected, but there should not be any attempt at analysis of specific problems in the initial phase.

As soon as the study design has been received and reviewed, decisions will have to be reached regarding the most effective way of carrying on the work outlined. In view of the complexity of the issues involved, it may be desirable to farm out specific segments of the work to appropriate not-for-profit or profit research institutions.

While there is need to undertake a broad study to develop a suitable framework for considering energy issues that cut across government and different energy sources, there is still a legitimate need for other more limited studies. We have in mind the updating of the National Power Survey now under way by the Federal Power Commission and the study of the long-term adequacy of petroleum supplies by the Department of the Interior. The Natural Gas Survey contemplated by the Federal Power Commission would contribute important information, but its terms of reference should be reviewed in relation to the study proposed herein.

Past experience shows not only the need for a comprehensive framework for consideration of energy resource policy but also reveals the essential need for a small, central staff mechanism, linked to policy decision-making at the Presidential level, to analyze and coordinate the study of specific energy issues and develop policy alternatives in the light of (a) the broad considerations previously referred to and (b) the interaction of Federal agency mission interests. To function effectively this mechanism must be located separate from the pressures, self-interests and jurisdictional limitations that inevitably condition the attitudes and flexibility of the responsible operating and regulatory agencies.

These two requirements--proximity to Presidential decision-making and institutional objectivity--can best be satisfied by locating this staff within the Executive Office of the President and having it report to a person who has access to the President and can deal at the Cabinet officer level.

The Task Force has noted various possibilities for housing such a staff, including the Council of Economic Advisers, the Office of Science and Technology, and the Bureau of the Budget. There are other possibilities such as the creation of an independent office of national energy policy in the Executive Office of the President. Since this question of organization for dealing with national energy policies must be considered in the broader context of the organization and function of the Executive Office of the President, the Task Force recommends that the matter be referred to the Bureau of the Budget for study and recommendation to the President.

Without the existence of such a mechanism it is doubtful that broad studies of the issues underlying national energy policies can have any real impact on the specific policy problems and decisions that call for early examination and resolution.

Conclusions and Recommendations

1. (a) That there be established in the Executive Office of the President a small staff having responsibility for the analysis of energy policy questions on a government-wide basis, for coordinating studies of such questions by governmental agencies or outside institutions, for developing policy alternatives, and for taking leadership to bring about a coordinated approach to the resolution of energy policy issues. The staff should have contract authority and funds to finance special energy studies.

   (b) That the Bureau of the Budget be requested to conduct a study and make recommendations to the President on the most appropriate organizational arrangements for locating such an energy policy staff in the Executive Office of the President.

2. That a contract be let with a non-profit organization to design a study that will develop a statement of energy goals and policy objectives and provide a framework to guide consideration of

specific energy issues confronting the Federal agencies in achieving the most efficient use of energy resources in terms of the total national interests.

3. That the Task Force on Natural Resources make arrangements for the preparation of the study design, arrange for its financing and, upon its receipt, make recommendations for the conduct of a follow-on study or studies in depth, depending on the outcome of the study design.

4. That a Presidential Commission on National Energy Policies be considered only if the comprehensive study of national energy policies develops specific policy approaches that warrant public examination and discussion, and Executive and Congressional action.

ATTACHMENT A

Design of A Study of National Energy Policies

Design Objectives

To design and recommend the organization of a study that will provide a comprehensive framework for the analysis and development of national energy policies over both the long and short terms.

General Considerations

The organization approached would be asked to submit a proposal outlining its concept of the area to be covered which should include at least the following considerations.

Any study or studies which provide the analysis for developing national energy policies to meet energy needs most efficiently must relate these policies to the nation's economic goals--rapid economic growth, efficient use of resources, satisfactory international monetary and resource relationships, improving quality of the environment, adequate resources for national security and others. The first step should be to analyze current and anticipated supply and demand relationships of all fuel energy resources combined. Second, the relationship of each energy resource with each other should be identified and evaluated. For instance, what is the likely effect of an increase in cost of gas in increasing the demand for electricity or oil? What is the impact on the mix of energy resources with a rapidly increasing standard of living and changing consumption habits? To what degree are fuels substitutable and to what degree are they not? Very little analysis has been made in this area. Third, after determining the interrelationships of energy resources of both supply and demand, then each energy resource--e. g., oil--should be analyzed. Fortunately, several studies written during the past decade can be helpful. The current and anticipated requirements and supplies of each energy resource should be evaluated.

TUNNELING TECHNOLOGY

Problem

The tunneling needs of the nation, many of which derive from Federally-supported programs, are already large and can be expected to grow rapidly. Sub-surface facilities will become more and more essential as urban areas expand, land costs rise and demands are made for both increased mobility and improved environmental quality. Tunneling will be an important element in

- urban design
- high speed ground transportation, including inter-city transportation through densely populated areas
- urban highway transportation
- mass rapid transit
- urban utilities (power, water, gas, sewers, telephone, refuse disposal)
- high voltage transmission
- water transportation
- oil and gas pipelines
- minerals extraction

The technology is at hand for improvements in tunneling speed and moderate reductions in cost. Over the longer run there is a distinct possibility that new technology may be developed which will result in further significant reductions in construction time and costs.

At the present time insufficient research and development effort is being expended by industry and educational institutions which directly relates to the long-run advancement of tunneling technology. Neither industry nor government is allocating substantial resources for the improvement of tunneling systems. Federal concern and responsibility is divided among many agencies, equipment manufacturers are not research oriented, and large, sophisticated corporations have not yet grasped the market potential, perhaps because the market will be determined largely by government decisions.

Appropriate government action can shorten the time required for a major change in industrial and construction technology. When the scale and character of the future tunneling markets become more clearly established, industry can be expected to maintain the necessary systems design and engineering development effort although continuing governmental support of scientific and engineering research and exploratory development may be required.

The initial steps to be taken by the Federal agencies would include the following:

1. Rock Disintegration

   - scientific research in rock mechanics, fracture, crystalline structure, etc.

   - state-of-the-art study of rock boring

   - rock disintegration machine concept studies

   - feasibility studies of new methods of rock fracture and weakening

2. Materials Handling

   - systems study of muck removal

   - research on hydraulic transport of rock particles

3. Ground Control

   - state-of-the-art study of tunnel linings and other artificial support systems

4. Environmental Control

   - study of environmental control requirements for continuous tunneling and evaluation of existing systems

5. Pre-excavation Sub-surface Analysis

   - research on remote measurement of rock mass features and conditions

- development of geologic inference methodology

6. Advanced Systems Development

   - preliminary assessment of alternative concepts
   - development of tunneling system simulators
   - development of evaluation methodology
   - design of field tests and demonstrations

7. Tunnel Requirements and Utilization Studies

   - feasibility studies of multi-use tunnels
   - definition of tunnel requirements of specific Federal programs such as Sewer and Water Facilities Grants, Civil Defense, etc.
   - definition of physical characteristics of tunnels which are primarily determined by end use

Conclusions and Recommendations

1. A government-wide program should be established which would provide for support of tunnel drilling system feasibility studies, exploratory and advanced development, and the supporting research. Federal support of engineering design, systems construction, and demonstration should be deferred until feasibility is better defined and the potential roles of government and industry are better understood. First year emphasis should be given to state-of-the-art studies, preliminary assessment of alternative concepts, tunnel use studies, and fundamental research. The program concept is detailed in the attached report by the Task Force Sub-Panel on Tunneling Technology (Attachment A).

2. Arrangements should be made in the FY 1968 budget for the first year expenditures of $4.6 million to avoid excessive delay in systems development and to generate essential sources of competence in industry and in selected university departments. Key agencies involved

in funding the first year program should be Interior, Transportation, and HUD. It is likely that to some extent this expenditure could be absorbed by Bureau of Mines and the Office of High Speed Ground Transportation. Attached is a statement of the first year funding requirements allocated among the interested agencies.

Although this expenditure could be deferred in the face of budget stringencies, it assumes urgency in the face of the very large present and prospective financial commitments by Federal and local governments for urban and inter-city transportation, urban utilities, and water supply that could benefit substantially from improvements in tunneling technology.

3. The involvement of several Federal agencies requires effective program coordination and comprehensive government-wide planning. This responsibility should be assumed by the Director of OST during the immediate future and program leadership needs should be re-evaluated next year. A planning committee is required with membership drawn from OST, Commerce, Transportation, Interior, DOD, and possibly AEC. A full-time executive secretary should be provided by the Department of the Interior. HUD

4. The Department of the Interior should proceed with its arrangements with the National Academy of Sciences-National Research Council for a study of the requirements for and the potential benefits that will derive from major improvements in earth excavation technology. This should help provide a basis for determining interim and long-range goals, priorities, and required level of effort.

Tunneling R&D Program - First Year Funding Requirements

Rock Disintegration	$600,000	Contract research and state-of-the-art study
Materials Handling	600,000	Contract research and systems study
Ground Control	400,000	Contract state-of-the-art studies of artificial support
Environmental Control	300,000	Contract systems analysis study
Subsurface Measurement and characterization	700,000	Contract research
Advanced Systems Development	1,300,000	Contract systems studies, analytical studies
Tunnel Requirements and Utilization Studies	500,000	
Program administration and management	200,000	
Total First Year	$ 4,600,000	

Note on program responsibility

No attempt has been made to divide rigorously responsibility for funding or implementing the first year program among the interested agencies. As a first approximation it has been assumed the Bureau of Mines would have primary responsibility for the first four program items (rock disintegration, materials handling, ground control and environmental control). Geological Survey is the probable lead agency in subsurface measurement. HUD and the Dept. of Transportation (particularly OHSGT) would bear primary responsibility for advanced systems development and tunnel utilization studies.

11/23/66

Natural Resources Task Force

Report of the Sub-Panel on Tunneling Technology

1. TUNNELING REQUIREMENTS

The utility of subsurface excavations for civil and military use has been recognized since the earliest eras of civilization. Tunneling in its true technical sense, is believed to have been started about 3500 BC during the Bronze Age in pursuit of copper ore on the mountain slopes of the Sinai Peninsula. Tunnels in ancient times were driven chiefly for the development of minerals, but many were also driven for other purposes including tombs, temples, military needs, water supply, and public passageways.

The current uses of subsurface excavations have changed very little from earlier days. The major difference now is in the number, size and sophisitication of the subsurface structures required. The subsurface is and will be excavated for such purposes as mineral extraction, transportation, hydroelectric facilities, utility distribution networks, underground storage, and underground facilities and shelters.

In the past, most urban tunneling has been a last resort (a) to negotiate barriers of water, (b) to pass through and under highly developed areas of buildings, (c) to preserve ground-level beauty in a few nationally significant sites, or (d) to provide exclusive right-of-way for transportation systems whose vehicular speed and use of live third rails make dangerous the proximity of pedestrians to the right-of-way. The future is likely to see expanded requirements for and uses of tunneling in urban environments, as open planar space becomes more scarce, land becomes more costly, and the number and complexity of utilities which may be combined in common tunnels increases.

High Speed Ground Transportation

There are very significant advantages to be gained by the use of subsurface routes for high speed intercity transportation systems. Unfortunately, present costs and time for tunnel construction tend to make tunnel solutions less attractive economically than surface routes. The prospect of major advancements in tunneling technology, however, opens many possibilities for the future development of economically and technically feasible subsurface systems. Furthermore, the spiraling of real estate values due to urban sprawl, particularly in metropolitan fringe areas, is aiding in closing the economic gap between surface and subsurface choices.

In the development of ground transportation systems the problem of safety, increases dramatically with speed. Grade crossings, as we know them today, must inevitably be eliminated in progressing to higher speed regimes. This is of course not always possible with vehicles which are sensitive to vertical grades, and in areas which are densely developed. Open guideways on the surface are also subject to acts of vandalism, flying objects and various obstacles which may cause collision or derailment. Furthermore, climatic and weather conditions can readily disrupt service or schedules, and interfere with the proper functioning of sensitive fixed equipment, especially that related to system control and safety. On the basis of these factors alone strong arguments, and indeed perhaps necessity, can be generated for using enclosed guideways in future systems.

Improved ground transportation systems for possible future use in the corridor area between Washington and Boston seem certain to require extensive tunneling. Certainly, the functional characteristics of any such subsurface routes will be expected to exhibit a far higher standard of performance than is satisfied by current systems. For instance, curves must be greatly reduced in curvature to keep accelerations at high speed within tolerable limits. It also follows that the maintenance of guideway alignment will be most critical, and improved methods and techniques will be needed for the prediction and correction of guideway distortions due to tunnel settlement, subsurface tectonic forces, and other instabilities.

The aerodynamic and dynamic characteristics of tunnels must not degrade vehicle performance. "Fail safe" design concepts incorporating means for detection of incipient degradation of failure will be needed, as well as efficient means for evacuation and protection of life in the event a failure should occur.

Terminals must be accessible and provide easy interchange capability for transfer of passengers between modes. Penetration of metropolitan centers probably will be necessary and a satisfactory surface right-of-way suitable for high speeds is not likely to be available. No other choice may be available but to go subsurface. In such cases "cut and cover" tunnels might be economically desirable. Unfortunately, it has been found in numerous urban systems that resorting to the construction of deeper tunnels is in many cases cheaper than attempting to relocate underground utilities.

Multi-purpose tunnels featuring a cellular cross-section could accommodate a variety of public utilities in addition to transportation, for instance electric power, communications, gas, water, - and even the mail. The potential economic advantage of having each of these users bear a proportionate share of the cost is obvious. Determination of technical and economic feasibility must of course be based on detailed studies and analysis.

An underground system for the Washington to Boston route might involve tunneling costs in excess of one billion dollars. It has also been estimated that hundreds of miles of new tunnels for transportation purposes will be constructed world-wide between 1966 and 1970.

Urban Highways

As urbanization progresses and automobile ownership continues to rise, transportation in metropolitan areas becomes more costly, more congested and more unappealing esthetically. The substitution of vehicle tunnels becomes more attractive as land costs rise and community opposition to new highway construction develops.

To be sure, near the hub of some U.S. cities, vehicular tunnels (such as those leading into Manhattan) or subterranean parking facilities (as in Boston, San Francisco, Los Angeles, and New York) already exist or are being planned. But in no instance are the tunnels connected directly to the parking facilities and in most situations they account only for a very minute portion of the vehicular volume.

George Hoffman of RAND analyzed tunneling cost trends and total urban highway cost trends and concluded that we are entering a period in which it will be no more expensive in the high density regions of many American cities to move and park cars underground than on the surface. Hoffman's trend assumptions have been attacked by others primarily because sample size is small and geographic factors such as sub-surface conditions have a great impact on cost. Nevertheless, in recent years tunnel costs have ranged from $4 - $14 million per lane mile equivalent while urban highway total costs have ranged from $1 - $6 million per lane mile. Cost estimates of urban highway land acquisition are continuing to rise.

Subsurface highways do require some additional operating expenditures for ventilation and lighting but these are balanced by savings in landscaping, snow removal and other maintenance costs. The land consumption of surface highways does force the city to forego tax revenues, an element seldom considered in cost comparison. Although tunnels may present some safety and driver acceptance problems they also eliminate some other safety and urban dweller acceptance problems. Better tunnel alignments may permit higher vehicle speeds but sight distance on curves is limited.

Tunnel parking appears to be highly expensive even where geologic conditions are favorable. Hoffman found that multi-story parking structures were less expensive and proposed linking underground highways directly to such facilities. No studies have been made of the economic of eliminating all surface vehicular transportation in a large portion of a metropolitan area.

A major underground highway project would generate a large tunnel requirement. Hoffman's commuter system would require 1,000 lane miles of tunneling in Los Angeles exclusive of parking facilities. Chicago would require 1,300 land miles. In each case the highway would cost at least one or two billion dollars and the parking facilities even more.

It is not clear what impact development of an automated personal vehicle would have on the demand for tunnels. It is theoretically possible that present freeway capacity could be increased by an order of magnitude after conversion to a wholly automated system. Parking requirements would be increased unless vehicles were available for rental throughout the day or were stored on the system until called. On the other hand the controlled environment and alignment of a tunnel might make it preferable for automated system use, especially at higher vehicle speeds.

Mass Transit

Investment in exclusive right-of-way urban transit is on the increase. A new subway system has been opened in Montreal, the Toronto system has been extended on a surface right-of-way, and plans are being implemented for a rapid transit service between downtown Cleveland and the airport. Seattle's proposed transit system makes extensive use of tunnels as does the Atlanta system. Massive plans incorporating extensive use of tunnels have been prepared in New York, Philadelphia, Boston and Chicago. It is now estimated that at least fourteen large scale transit systems will be constructed in the U.S. during the next twenty years.

The San Francisco BART provides some indication of future tunneling requirements. As originally designed the billion dollar, 75 mile system was to have 16 miles of tunnels and subway in addition to a four mile tube under the Bay. Recently Berkeley added a few subway miles by voting an additional $20 million bond issue to put its entire section underground. It is anticipated that additional mileage may be built through populous San Mateo county where the original proposal was rejected.

Within the next several years (1967 - 1975) there will be approximately 100 miles of subway construction in the eleven cities discussed in the Gerhardt Report. It is possible that 20 miles or more will be built in other cities that are now discussing rapid transit projects. At a minimum cost of $10 million/mile, the projected 100 miles of tunneling for mass transit subways would require an expenditure in '66 dollars using present technology of $1 billion exclusive of rail and equipment costs. The impact of improved technology upon the direct cost of tunneling is not nearly as important as the elimination of disturbance to surface activities, shallow foundations and sub-surface utilities. Of course, a reduction in direct tunneling cost would itself change the distribution of right-of-way among surface, elevated, and underground categories and might in some marginal cases generate an increment in the demand for rapid transit. In the near future, rapid transit systems will make extensive use of under-utilized railroad right-of-way, but over the long run other solutions to right-of-way acquisition must be found.

Cities will continue to depend heavily upon bus transit, either exclusively as in the case of small and medium size cities or as an important element in a composite system. Many opportunities exist for improving the average speed and convenience of buses. Effective use could be made of underground distribution loops and bus stations in the most heavily congested parts of a city. It is possible that the tunneling requirements of bus systems may match or exceed those of rapid transit several years hence.

Urban Utilities

During the next 30 years the demand placed upon urban utilities - power, utility systems will require expansion or replacement and entirely new systems will be required to serve the 30,000 square miles which will be converted to urban use. Over this period a capital expenditure of $700 billion in '66 dollars will be required to meet utility demand if present technology is not altered. A large part of this investment will be used to improve or extend utility distribution systems.

Public demands for improvement in environmental quality are likely to increase the cost of utility distribution in the absence of greatly improved technology. Ripping up of streets to repair cables and sewer pipes may become highly undesirable due to traffic and noise considerations. Antipathy toward handling refuse may lead to the use of vacuumatic systems or water transport of waste. Greater opposition can be expected to overhead wires. These problems can be minimized or eliminated in heavily built-up areas by the orderly integration of all utility lines in a single underground structure or "utilidor". Extensive construction of such utilidors with present excavation technology would be very expensive, time consuming and objectionable to urban dwellers during the period of construction. An improved tunneling technology would reduce the extra capital cost requirement to convert to utilidor systems, speed progress and leave roads relatively undisturbed. Firm forecasts of urban utilidor requirements have not been made but the construction of more than 100 miles of multi-purpose utility tunnels annually in central city areas by 1980 is possible although a substantial part of the mileage may be constructed as one element in a large construction project requiring extensive surface excavation. Successful use of utility tunnels in one or more urban renewal or demonstration city areas could accelerate overall demand.

The current expenditure for utility tunneling is not known. Almost all underground facilities have been constructed with the use of cut and cover techniques. In the future, disruptions created by open excavations will become less acceptable and tunneling more attractive. Development of efficient tunneling machines may also reduce the cost of constructing large diameter interceptor sewers and primary water supply installations.

Mineral extraction

The development workings of a mine (shafts, raises, winzes, drifts and crosscuts) that are driven to gain access to an ore body are essentially tunnels and related vertical openings used in conjunction with tunneling. New tools and techniques dev eloped either in mining or tunneling are rapidly adopted for both purpose.

In 1965 there were more than 220 miles of development workings driven in the metal and nonmetal mines in the United States. The estimated cost of development work is $93 million. While comparable figures on development workings in coal are not readily available it is estimated that an equal or greater length of development workings are driven in U.S. coal mines.

The latter, however, were driven primarily in coal.

Over 150 million tons of crude ore were produced in 1965 from the underground metal and nonmetal mines in the U. S. that required 220 miles of development workings. It is estimated that crude ore production from such mines in 1980 will exceed 250 million tons or a 67 percent increase. On this basis the "tunneling requirements" for mineral extraction in 1980 would be 367 miles and the estimated cost $155 million. The estimated requirements for 1980 are probably low. The grade of ore being mined is continually declining requiring that a larger tonnage of crude ore be mined to obtain an equivalent final product. This, in turn, will require an additional footage of development workings. In addition, new mines are usually deeper. Another factor that would increase the development footage is the public reaction against surface mining operations that scar the land surface and contribute to stream pollution. This is already resulting in restrictive legislation with respect to surface mining that could result in increased mineral extraction by underground methods.

The demand sensitivity of tunneling costs for mineral extraction is closely related to the price of mineral commodities. This is tempered, however, by the national need to maintain a domestic mineral industry to minimize dependence on a foreign source of supply for commodities essential to our economy.

Water distribution

The requirements presented are limited to large scale projects of the type undertaken by the Bureau of Reclamation and Corps of Engineers. The following data were available from the Bureau of Reclamation and the Corps of Engineers and comprise the major segment of tunneling requirements in this category.

Current contracts of the Burea of Reclamation require 46.5 miles of tunneling at a cost of $67 million. The average tunnel contract takes about 3 years to complete so the average annual requirement would be about 15 miles and the cost $22 million. The program is geared to approval and funding by the Federal Government and projections of requirements to 1980 do not anticipate any material change in the requirement. Tunneling requirements of the Corps of Engineers in 1965 are 11.5 miles at an estimated cost of $64 million. The projected requirements in 1980 for the Bureau of Reclamation are 26 miles of tunneling at an estimated cost of $205 million. These projections could be changed radically, however, requiring a several fold increase if any decision were made to proceed with any one of several bold proposals that have been presented for large scale water projects such as the North American Water and Power alliance.

Excluded from the data presented here are the water distribution projects of the major metropolitan areas such as Los Angeles and New York. Several metropolitan areas have substantial tunneling requirements but the data were not available for the inclusion in this report. It is estimated that the requirement would range from 1/3 to 1/2 the combined requirements of the Bureau of

Reclamation and the Corps of Engineers or on the order of 20 to 30 miles at a cost of $32 million to $50 million.

The demand sensitivity of tunneling costs with respect to water distribution generally is not a critical factor. Usually tunneling is only one element of a water distribution project and frequently is not the major cost element of the project.

Power distribution

The FPC reports that a total of 1600 miles of underground transmission lines are now in service in the United States. Long distance underground transmission of high voltage AC involves either high facility costs or large scale energy losses. However, demand from the public based on aesthetic ground coupled with increasingly high costs of surface right-of-way are tending to limit the use of overhead transmission lines within a radius of 30 miles of our major cities. Much of the 3,000 miles of transmission lines located in the vicinity of our largest cities will eventually be relocated underground. Based on present technology this would involve an investment of $1.5 billion.

What portion of this work could strictly be classified as tunneling is indeterminate at this time but a major portion will be subsurface excavation of some type. Tunneling requirements are undoubtedly highly sensitive to cost. However, public demand for beauty and convenience is expected to be a determining factor in many cases. This is already being demonstrated with respect to underground service lines in residential areas.

Oil and gas pipelines

No information was assembled about oil pipelines. The Nation's interstate natural gas transmission network contains over 150,000 miles of pipeline. Plant investment exceeds $11 billion. Gas transmission capacity increased fifteenfold since 1938 and natural gas now provides approximately 30% of total national energy requirements. The typical cross-country right-of-way contains one or more 12 to 42 inch diameter pipes laid two to three feet below the surface. Deeper tunnels are often required in rugged terrain, to cross highways and railroads and in some urban areas. No estimate of future requirements for either shallow trenching or tunneling has been obtained. The role of tunneling machines appears to be a limited one.

2. ONGOING RESEARCH AND DEVELOPMENT AND DEMONSTRATION

There is presently a modest national research and development effort for improving subsurface excavation technology. Within Government, the Bureau of Mines and the Department of Army and Air Force sponsor or do most of the research while the Bureau of Reclamation, Office of High Speed Ground Transportation, and Geological Survey contribute a relatively smaller amount. The total Federal expenditure is approximately $5.7 million - two thirds of the funds in scientific research and one-third in the advancement of technology. Industry's effort is limited primarily to improving the capability of their own specialized equipment which has evolved during past decades. It is usually in response to tunnel contract proposals. A recent significant contribution was the development of mechanical boring machines. These machines have been developed over the past 15 years and are still in the early development stage. At the present time machine tunneling is limited to relatively low strength sedimentary rocks.

Federal Support for Scientific Research in Geology, Soil Mechanics and Rock Mechanics

Most of the research is being done or sponsored by the Departments of Army ($1.1 million) and Air Force ($1.2 million) and the Bureau of Mines ($1.0 million). Practically all of the Army's and Bureau of Mines research is done in-house while a large share of the Air Force's research is contracted to the academic and to a lesser degree to the industrial community. A large portion of the Army's and a greater part of the Bureau of Mines' rock mechanics research is concerned with ground stability. A significant part of the remaining rock mechanics research is directed towards rock disintegration or structural failure and a smaller part towards the handling properties of the broken rock.

Phenomena being investigated in the laboratory include dielectric and induction heating, electrohydraulic force, thermal shock, erosion with pulsed high pressure water jets, and chemical pretreatment.

Research on subsurface geologic structure is being done by the Department of Air Force and the Geological Survey. The current annaul budget level is approximately $0. 5 million. Geophysical studies are being made to measure the physical properties of the earth (magnetic, gravity, electromagnetic, radioactivity seismicity, heat flow) and to interpret these measurements in terms of geology.

Federal Support for Tunneling Technology and Related Engineering Research

The combined current annual research expenditures on evaluation of subsurface conditions, rock disintegration, ground and environmental control, materials handling, and systems design and evaluation is approximately $1. 9 million. Essentially all of the research is being done or sponsored by the Bureau of Mines (1. 6 million), Department of Army (0. 2 million), and the Office of High Speed Ground Transportation (0. 1 million).

Most of the research is concerned with ground control and design of underground openings ($1.2 million). Only a minor part of this research is concerned with improving artificial methods of supporting underground openings. The total engineering research effort relative to rock disintegration methods is approximately $0.3 million. This includes studies of energy transfer and rock failure mechanisms related to mechanical drilling or boring, high pressure water jet extraction, and a high temperature flame jet method of rock cutting. A small materials handling program is exploring the transportation of rock hydraulically in pipelines and mechanically on a novel undulatory conveyor. Efforts are also being made to improve prediction and control of gas, water and dust encountered during excavation. In the area of systems design and evaluation operations research techniques, such as as mathematical statistical analyses, critical path methods, and linear programing are being applied to optimize excavation systems design and production and construction planning, and to evaluate the gross physical situation to be encountered during excavation.

Government R & D Activities Related to Rapid Excavation

Science		
Rock Mechanics		
Opening design	$2, 800, 000	Bureau of Mines, Army and Air Force
Rock disintegration	460, 000	Bureau of Mines
Materials handling	50, 000	Bureau of Mines
Subsurface measurement and characterization		
Geophysics	500, 000	Air Force and Geological Survey
Sub-total	$3, 810, 000	
Technology		
Rock disintegration	300, 000	Bureau of Mines and Office of High Speed Ground Transportation
Materials handling	170, 000	Bureau of Mines
Ground Control	1, 200, 000	Bureau of Mines, Army and Bureau of Reclamation
Environmental Control and predicition	150, 000	Bureau of Mines
Systems analysis and design	80, 000	Bureau of Mines
Sub-total	$1, 900, 000	
Total	$5, 710, 000	

Industrial Research and Development

Considering the magnitude of the excavation related construction industry, it does or supports very little research and development. This was substantiated in a recent annual report by the President's Council of Economic Advisers. The most common methods of rock disintegration is by mechanical drilling and high explosive blasting whigh were introduced simultaneously a centu ry ago. Essentially the same can be stated for other elements of the excavation system such as materials handling and ground support.

Analysis of industrial research and development activity in rapid excavation indicates the greatest effort is concerned with equipment development, primarily the mechanical boring machine. The boring machine was developed for and introduced by the depressed coal industry in the early 1950's. Since then the machine's capability has been extended to the boring of soft rock, primarily as a result of research and development of vertical drilling rigs and cutting bits by the oil industry. Conservative attempts to develop harder rock boring machines have failed. In addition one boring machine manufacturer has developed a method for guiding boring machines using a laser beam. Mechanical and flame jet drilling research carried on by industry for the drilling of small rock holes may prove helpful in advancing the technology of boring large holes. *

* The Office of High Speed Ground Transportation currently is soliciting proposals for a study to investigate the feasibility of use of flame jets for full face tunneling.

A serious industrial limitation has been the almost complete disregard of the other parts of the excavation system. Practically no research and development, appropriate to the development of high-speed tunneling technology, is being done to improve materials handling, artificial ground support, or methods of controlling the environment. (water, gas, dust, heat, noise) during excavation. Nor is industry doing any research to improve the accuracy and cost of delineating the subsurface environment, including geology, prior to excavation.

Industrial expenditure for research and development related to rapid subsurface excavation probably does not exceed $4 million annually.

3. PROMISING TECHNOLOGICAL OPPORTUNITIES

The miner and tunneler have long visioned a "mechanical mole" or continuous mining machine that would speed his work and lighten his labors. During the past 15 years this vision has become at least a partial reality, as inventors have begun to utilize improved metals, bearings, power systems and other available technology.

The earliest application of a tunnel boring machine was in the 1880's in an unsuccessful attempt to drive a tunnel in soft chalk under the English Channel. The first widely accepted commercial application of this principle was the introduction subsequent to World War II of the continuous mining machine for mining coal. Within the past 10 years the principle of full face tunnel boring has been successfully employed in a few special situations.

Advanced boring systems

A major obstacle to more efficient tunneling systems has long been the cyclic nature of the proved and conventional method of drilling, blasting and loading out the rock. Improvements to this system can at best provide only incremental advances in the efficiency of the process. A continuous rather than cyclic process to accomplish this purpose offers the best opportunity for a major technological advance. The present generation of tunneling machines (Robbins, Hughes, Alkirk, Jarva, Calwell, et al) now accomplish that purpose within certain specific rock conditions. How rapidly this method is being introduced is illustrated by the fact that 30 of the 46.5 miles of tunneling requirements of the Bureau of Reclamation in 1965 anticipate use of the boring method.

Machine development for this purpose is in a very early stage and some of the first generation prototypes are still being tested. The emphasis, both in research and development, has been on rock fragmentation with little or no work on the associated system components: loading and transportation of the broken rock, determination and prediction of rock properties and conditions prior to excavation, is an essential element for general wide-spread successful application and ground support and environmental control.

If full advantage is to be taken of continuous tunnel boring machines they must be considered as one element of a new system of tunnel driving. Presently developed machines are limited to "soft rock" having a compressive strength below 12,000 to 15,000 pounds per square inch. Unquestionably this limitation can be overcome by new designs based on matching the breaking action to determinable rock properties. New support methods tailored to the rock stress conditions and placed continuously need to be developed. A method for loading and transport of broken rock that is continuous and flexible for easy placement and advance should be designed.

Effective ventilation systems should be designed and provisions made for automatic monitoring, detection and prevention of any dangerous gas concentrations. In many situations water conditions can be determined in advance and appropriate measures provided to cope with predicted conditons. Most important, all these components of an integrated advanced tunneling system should be considered in relation to the total system.

The bored tunnel has many advantages including continuous operation, minimum disturbance of the rock, smooth perimeter and minimum over-break. The prime advantage though is the fact that continuous boring lends itself to automation of the operation and remote control of operations and conditions.

Unconventional Systems

A new rock breaking method could revolutionize tunneling technology. The unconventional methods to break rock that have been or are now under investigation include hydraulic, thermal, electric, sonic, chemical and varied mechanical means to fragment rock.

Hydraulic methods have been employed commercially and on a demonstration basis to drive tunnels (Minneapolis-St. Paul Sanitary District) and to mine coal and gilsonite. Research is continuing on a limited scale exploring basic theories, nozzle design, effects of pulsing, the use of solid additives to the jet streams and similar elements.

Thermal methods for breaking rock are now applied commercially for drilling small diameter holes. Referred to as jet piercing or flame drilling holes, 9 to 15 inches in diameter are drilled for loading with explosives in the mining of taconite. No attempt has been made to apply this method for full face tunnel breaking.

Sonic drilling (magnetostriction, vibration) has been demonstrated as feasible for small diameter drill holes but much background research and development remains before this method could be evaluated for tunneling.

The other unconventional methods mentioned have not progressed beyond laboratory investigations of the phenomena involved. Their practical application is several years distant even if an increased R&D effort is established now. In contrast, engineering improvements in boring machines and the development of an integrated boring system promise to reduce costs and construction time substantially in the next few years.

4. PROGRAM TASKS AND PRIORITIES

First Year Activities

Projects undertaken during the first year of the program would be designed to accomplish two principal objectives:

(1) Initiate an accelerated growth of the research and development capability, within the scientific and industrial communities, that will be required for rapid improvement of underground excavation technology.

(2) Gain lead time in the program by initiating selected scientific and technologic background studies to develop basic knowledge that will be required in order to evaluate the feasibility of advanced tunneling systems.

There is, within industry and the universities, particularly the aerospace and defense-oriented companies and DOD-and-NASA-supported engineering departments, a considerable amount of talent that can be applied in many parts of the research and development program. The task here will be largely one of orientation of researchers toward the problems of earth excavation and the training and development of research teams which can bring to bear on the problems.

Mining and tunneling equipment manufacturers are generally somewhat special ized, each making only a few types of machines. None could supply the equipment for a total system. Their research and development is largely limited to incremental improvement of items of equipment to gain a competitive advantage or to adapt a piece of proprietary equipment for a new use to broaden the market. It is often done by contract with little financial risk on their part. However, the manufacturers have excellent design and prototype construction capability and a sound understanding of the physical conditions under which their machines must work. The first year task here will be largely one of developing systems competence and orienting them toward the program objectives. It is possible that Federal interest in tunneling will encourage the association of equipment manufacturers with technically sophisticated systems development groups.

The research tasks that would be initiated during the first year to accelerate the development of the necessary R&D capability outside the Government and at the same time contribute to the long and short term advancement of tunneling technology can be derived by considering the functional elements that must be involved in any underground excavation system.

Any excavation system must comprise four major functional subsystems: (1) Rock Disintegration (2) Materials Handling, (3) Ground Control, and (4) Environmental Control. The optimum synthesis of these four subsystems into a total excavation system is dependent on the physical situation within which the system must function, so a principal requirement for the engineering design of any tunneling system is the delineation and characterization of the nature and properties of the rock mass through which tunnel is to be driven.

The detailed planning of the R&D to be done over the long term in each of these five problem areas must await a more intensive examination of technological problems, economic considerations and performance requirements defined by future tunnel use. Some of these issues will be clarified by the NAS-NAE-NRC ad hoc committee on Rapid Excavation and by the user agencies during the next 18 months. In any event the development of any new advanced system will require a better basic understanding of the nature and behavior of rock and near surface geology. The first year program will have three primary thrusts. First, the present state-of-the-art should be consolidated and focused on the improvement of boring machine systems. Second, the science underlying major changes in future technology should be strengthened, particularly in universities. Third, engineering feasibility studies should be undertaken to identify the most promising new system concepts and related technical problems in order to more clearly define second generation systems development requirements.

Research to be initiated during the first year will include:

(1) Rock Disintegration - Rock mechanics has been principally concerned with the structural stability of earth openings and foundations and rock fragmentation with explosives. Different basic work on rock failure is required for developing new concepts in continuous rock disintegration machines. A considerable reservoir of basic scientific knowledge and talent exists which can be utilized in this problem area, as a result of DOD, NASA

and AEC research programs on materials, seismic detection, etc. In addition to the reinforcement of in-house competence, additonal resources should be made available through university research. In a few promising areas, industry participation may be required during the first year to undertake rock disintegration machine concept studies.

A considerable amount of basic and applied research must be done before unconventional systems can be designed which utilize energy mechanisms other than mechanical for continuous breaking of rock. Therefore, the first generation of rapid tunneling systems will be developed around the continuous mechanical boring or mining machine. To provide the basis for designing such a program a state-of-the-art study of existing continuous boring machines covering performance as related to such factors as material deficiencies, bit design, thrust, and rock characteristics will be made, under contract. Mechanical engineering firms, closely associated with the equipment industry, are among the possible contractors.

(2) Materials Handling - Except for some work on hydraulic pipeline transportation and complex conveyor systems essentially no research and development in materials handling, applicable to high-speed tunneling systems, has been done. The present state-of-the-art and critical nature of this element of the excavation system with respect to overall excavation system efficiency dictates a major research and development

effort in this field. Substantial innovation will be required to obtain maximum effectiveness of even the present generation of boring machines. A truly continuous system for removal and transportation of broken rock from an advancing tunnel face would increase the efficiency of existing mining machines at least 50 percent.

The first year program will include, therefore, a systems study of underground muck removal to define performance requirements and examine alternative continuous excavation system concepts.

Very little research has been undertaken on the properties of broken rock particles and aggregates and the flow mechanisms involved in their loading and transport. An attempt should be made therefore to develop some capability in the more fundamental aspects of attrital rock transport.

(3) Ground Control - A substantial research effort is going on in the rock mechanics of ground control and underground opening design and existing capability in this field should be adequate for the program. Therefore, no additional research in this area is planned for the first year.

However, research or development is needed on artificial support and stabilization of ground around an underground opening through the use of tunnel linings and/or chemical grouting, particularly in relation to continuous tunneling systems. Therefore, during the first year background studies will be initiated to develop the state-of-the-art for available tunnel linings (both temporary and permanent) and other artificial support systems, and to determine their limitations with respect to rapid continuous tunneling systems.

(4) Environmental Control - Little research on the problems of ventilation, water control, gas emission, dust and temperature control and other aspects of the underground physical and working environment is going on. Furthermore, only a small part of the present program is applicable to high-speed tunneling systems. Therefore, during the first year a critical study and analysis of environmental problems associated with continuous tunneling systems utilizing existing boring machines, to definitively delineate the requirements of the environmental control subsystem elements of high-speed tunneling systems.

(5) Pre-excavation Subsurface Measurement and Characterization

A new and substantially superior set of techniques and tools will be required to measure and characterize with speed, economy, accuracy and precision the subsurface features and conditions that will affect the performance of the excavation system. Unexpectedly encountered changes in rock type, stress conditions, faults, water, and gas, for example, have caused trouble for construction men since the first tunnel was driven and will be even more disastrous where a high-speed, largely automated excavation system is used.

Though little research has been done on the problems of remote measurement of rock mass features and conditions on the scale and with the accuracy and precision required for high-speed tunneling, a substantial reservoir of the background information and geophysical capability necessary for much of the research exists in Federal, university and private laboratories.

Contracts and grants in this area during the first year would serve to orient the appropriate segments of the scientific community toward the program objectives.

Another presently developing field that shows promise of providing valuable tools for characterizing subsurface conditions is the use of statistical response surface fitting techniques as a supplement to geologic inference and for modeling geological situations. The present limited capability now in the universities and the Department of Interior is not nearly large enough, and requires more people who combine the disciplines of geology and higher mathematics. Strategically placed grants during the first year would serve to stimulate the interest in this field necessary to develop the required additional capability.

(6) Advanced Systems Development - Savings in time and resources will be possible if an effort is made at an early stage to identify engineering requirements for a complete boring system. This effort should involve both experienced tunneling experts and systems designers. The first year study would include a preliminary assessment of alternative concepts utilizing readily available equipment and evolutionary technological improvements. Consideration would be given to remote control, subaqueous operation and failure modes. Special efforts would be required to coordinate parallel state-of-the-art and subsystem studies.

Certain rock breaking concepts imply a comprehensive change in environmental control, materials handling, etc. A few industrial contractors could be provided with study funds to explore the engineering problems associated with the utilization of thermal shock rock breaking, chemical weakening, rock erosion and other approaches. These studies would lead to more effective use of development funds in future years.

A methodology is required to compare alternative systems concepts taking into consideration the characteristics and locations of future tunnels. A program should be started on a small scale to define key performance and cost parameters. An evaluation methodology should include not only an analytical procedure but should also define essential characteristics of field tests and demonstrations, where necessary.

(7) Tunnel Requirements and Utilization Studies - During the first year the Federal agencies whose missions involve the construction or use of tunnels and other types of underground openings, should initiate studies to define urban and rural tunnel needs. Probable requirements of specific programs should be identified more clearly such as Basic Water and Sewer Grants, High Speed Ground Transportation, Urban Mass Transportation, Civil Defense, Interstate Highway and other programs. Physical characteristics of tunnels may differ in many respects depending upon its end use. These characteristics should be studied including depth, angle of grade, shape of cross-section, drainage and water proofing, ventilation, strength of retainer walls and roof, speed of construction, possible alternative use of cut-and-cover, radii of curvature, length, ancillary underground structure requirements and alignment.

It is anticipated that a broad study of rapid excavation, including tunneling, will be undertaken by the National Research Council of the Academies of Engineering and Science in parallel with the above mentioned projects. Funds for the 18-month committee activity ($73, 000) have already been allocated by the Bureau of Mines. The Committee will be asked to:

- - - - examine the importance of improving rapid excavation capability
- - - - explore the scope and adequacy of present research activity
- - - - identify areas of research and development requiring greater emphasis
- - - - provide recommendations for a general research program commensurate with rapid excavation problems and needs.

The membership of the committee would provide competence in engineering, sciences, economics, construction and equipment, and legal problems. Liaison representatives or consultants knowledgeable in tunneling and drilling problems, mining, transportation, civil and military works and other areas would be invited to work with the committee in special problem areas.

It is expected that the NRC committee will provide some program guidance well in advance of the eighteen month completion date. Also, the committee will make good use of the reports filed by contractors carrying out some of the state-of-the-art and tunnel utilization studies proposed as a part of the first year tunnel R&D program.

Tunneling R&D Program - First Year Funding Requirements

Rock Disintegration	$600,000	Contract research and state-of-the-art study
Materials Handling	600,000	Contract research and systems study
Ground Control	400,000	Contract state-of-the-art studies of artificial support
Environmental Control	300,000	Contract systems analysis study
Subsurface Measurement and characterization	700,000	Contract research
Advanced Systems Development	1,300,000	Contract systems studies, analytical studies
Tunnel Requirements and Utilization Studies	500,000	
Program administration and management	200,000	
Total First Year	$ 4,600,000	

Note on program responsibility

No attempt has been made to divide rigorously responsibility for funding or implementing the first year program among the interested agencies. As a first approximation it has been assumed the Bureau of Mines would have primary responsibility for the first four program items (rock disintegration, materials handling, ground control and environmental control). Geological Survey is the probable lead agency in subsurface measurement. HUD and the Dept. of Transportation (particularly OHSGT) would bear primary responsibility for advanced systems development and tunnel utilization studies.

Long Term Resource Requirements

Academic Research

Extension and expansion of the first year academic research described above should produce an adequate supply of engineering and scientific manpower of the disciplines required for the program. Beneficial changes in mining and civil engineering curricula can be expected if university research support is sustained.

Basic Technology

Research planned for initiation during the first year for the development of improved means of subsurface measurement, characterization and evaluation will ultimately provide an important part of the basic technology needed for high-speed tunneling systems. Present techniques involving geological mapping and subsurface probing through closely spaced drill holes will be completely inadequate with respect to speed, accuracy and economics. For example, even after preliminary geological study and route selection, the exploration and study required for design of a Northeast

Corridor high-speed transportation tunnel would take at least five years and be very costly. Furthermore, at best the information obtained would not be sufficiently accurate or precise enough to risk the use of a high-speed tunneling system.

Another area of basic technology that should be given early attention is related to communication and control. Laser guidance of the Hughes tunneling machine is about the only present development in this field. Some parts of the communication and control technology developed for space and defense applications will be useful but an essentially new area of basic technology will have to be developed because the machines will be working in a rock medium rather than air or water.

Systems Design and Exploratory Development

As indicated earlier the basic capability for tunneling systems design and exploratory development already exists among the defense and space contractors and the mining and construction equipment manufacturers. Development of the required resources here is merely a matter of education and integration of the two groups. This can be done by judicious structuring of the contract research and development program. Large-scale specialized test facilities may be required but this situation will be clarified during the first year. For example, it now appears that development of improved artificial ground support will require controlled conditions available only at a specially designed test facility.

Engineering Development, Prototype Construction and Evaluation

Most of the resources required in this area can be developed using the same strategy and in the same academic and industrial sectors as the capability necessary for systems design and exploratory development. However, evaluation of the systems and system elements will require on-the-job testing. It will be necessary therefore to make provision for management and funding of such testing. This should not present a major problem because the tunnel construction and mining planned for the next 10 years by Federal, state and local governments and the mining industry will provide a wide variety of test sites and tunnel characteristics.

In addition, in order to assure objective evaluation the Federal Government should maintain a sound in-house capability

Field Utilization of Tunneling Systems and Training

Use of tunneling machines in the field will speed the application of improved technology and help build greater industry competence. To date, however, the contractor has had to write off the entire cost of the machine on the job and in addition foot the bill for the break-in expenses associated with the first field use of a new design. Many agencies that design tunnels write specifications which unnecessarily hinder or prevent the use of tunneling machines. Furthermore, the fact that no standard dimensions are in common use limits the reuse of high speed-high first cost systems.

Within the Federal Government, efforts can be made to -

- - - - investigate feasibility of standardizing on tunnel sizes
- - - - make performance data available
- - - - develop and publicize specification writing procedures
- - - - undertake after-the-fact performance assessments of drill and blast and machine tunnel projects.

In addition, the provision of demonstration grants to contractors for machine testing and start-up costs should be attempted on an experimental basis.

Government-Industry Relationships

The purpose of the program is to stimulate a massive change in an area of technology with a long history of slow incremental improvement. The research and development program should be so designed as to be largely self-sustaining after a 10-year period.

Four segments of industry must be considered because each must play a role in the program and the approach, attitude and acceptance of the program of each will be somewhat different. The aerospace and defense industry will enthusiastically endorse the program because they are looking for additional markets for the diversification of their capabilities. This group must be a major contributor to the program but care must be taken at the outset to assure that they become quickly cognizant of the physical and economic boundary conditions within which the product technology must function.

The mining industry will probably accept the program and provide the necessary cooperation but, at least in the early stages, will be reluctant to risk their capital in testing machines and trying new systems.

The tunnel construction industry does little research but can be expected to participate in any Federally supported program. Furthermore, they will quickly see the additional market for their services that will result from the improved technology.

The equipment manufacturers will be the group most affected because success of the program may render obsolete their present line of equipment and radically change the market for the remainder. Their reaction to the program can be expected to be mixed. Some will be resistant. Others will see the handwriting on the wall and participate defensively. A few will see the opportunities and cooperate aggressively, to the extent of substantial investment of their own capital.

Extreme care should be taken therefore to initiate development of the right industry-Government relationship at the outset of the program. The first step should be to thoroughly acquaint them with the goals and objectives of the program. The Academy study, which will require participation on the part of industry, will contribute in this regard but it should be supplemented by meeting with industry and trade associations such as AMC and AGC, together with publicity and participation in the planning of the program on the part of industry. Formation of an organization something like NSIA, but with interests limited to earth excavation technology should be encouraged.

A study should be initiated during the first year to examine the impact of the program on the equipment industry and determine means for assuring an orderly transition and minimizing the danger of excessive financial losses by industry. It should be emphasized from the outset that the Federal Government will not manufacture systems or procure systems for government contractors. The Federal Government will undertake research and some systems development, design and prototype construction, provide opportunities to test new or improved systems, and generate - directly and indirectly - a major market for tunnels.

Program Planning and Implementation

Since a major part of the basic and applied research will pertain to all tunneling systems, at least in the early stages of the program, and much of the technology developed will be common to many systems, careful attention must be given to the development of appropriate mechanisms for program planning and operation if overlap and duplication and gaps are to be avoided.

Good communication among interested Federal agencies must be maintained and also must be developed and maintained with industry and the academic community. The existing informal interagency committee on rapid excavation should therefore be reconstituted as a Committee under the leadership of the Director of OST and consideration should be given to the establishment of a standing committee in the National Academy of Engineering.

One agency should provide a focus for program planning and coordination by providing a full-time executive secretary to the OST committee and by flexibly administering its own R&D resources in order to maintain a balanced overall-federal effort. It would be expected that activities of all agencies would be a part of a comprehensive Federal program. The long term scientific and engineering research would be supported by the "executive" agency. In contrast, user agencies would be expected to be primary supporters of large scale demonstration programs. Several agencies might be involved in systems development and coordination will be required through the preparation and implementation of annual plans.

In order to preclude overemphasis related to the executive agency's mission the tunneling technology program should be managed as a separate program, distinct from any now existing activity. The program management group would be responsible for all tunneling R&D activities within the agency including that done by in-house laboratories.

The government-wide program would be developed jointly by the executive agency program management group and the other members of the interagency body supplemented by advice from the NAE/NRC. Periodic review of the program by the Director of OST would assure proper assignment of priorities and distribution of the research to accomplish the program objectives.

By reason of its in-house mining research capability and experience in underground excavation technology the Bureau of Mines is the logical executive agency for the tunneling technology program at this time.

The first year's program operation should be funded largely by the Bureau of Mines, the Office of High Speed Ground Transportation, and HUD. If the Bureau of Mines is assigned the executive agency role it should be provided with the resources to implement a large part of the first year program.