REPORT TO THE CONGRESS

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

Federal Materials Research And Development: Modernizing Institutions And Management

GAO made three recommendations aimed at moderninzing the materials policy formulation process and the management of Federal materials R&D activity:

--The Congress should consider establishing an institution to analyze national materials issues and provide policy guidance on a continuing basis.

--A comprehensive unclassified information system for materials research and development should be established, building on existing information in the Smithsonian Science Information Exchange.

--The Science Exchange should include in its information system data pertaining to material research and development outside the Federal Government.

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COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

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To the President of the Senate and the
Speaker of the House of Representatives

This report, titled "Federal Materials Research and Development: Modernizing Institutions and Management," deals with issues of importance to the entire Congress.

The report was generated by a request from Senators William Brock and John Tunney, Senate members of the National Commission on Supplies and Shortages. They asked GAO to analyze Federal funding for materials research and development (R&D) and to evaluate the effectiveness of Federal materials R&D.

The report reveals important deficiencies in institutional arrangements and information systems bearing on national materials problems. It looks beyond research and development as such and identifies the institutional setting which must be created for articulation of coherent national materials policy goals. Their stipulation must necessarily precede and serve to guide the establishment of research and development priorities. It contains recommendations for action that should be taken by both the National Commission on Supplies and Shortages and Executive Branch agencies to achieve a modern capability for formulation and execution of a national materials program.

Our review was made pursuant to the Budget and Accounting Act, 1921 (31 U.S.C. 53), and the Accounting and Auditing Act of 1950 (31 U.S.C. 67).

Copies are being sent to members of the National Commission on Supplies and Shortages; Director, Office of Management and Budget; heads of agencies represented on the Executive Branch Committee on Materials; Director, Smithsonian Science Information Exchange; and Director, Office of Technology Assessment.

Sincerely yours,

Elmer B. Staats

Comptroller General
of the United States

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ABBREVIATIONS

GAO	General Accounting Office
R&D	research and development
SSIE	Smithsonian Science Information Exchange

COMPTROLLER GENERAL'S REPORT TO THE CONGRESS

FEDERAL MATERIALS RESEARCH AND DEVELOPMENT: MODERNIZING INSTITUTIONS AND MANAGEMENT

DIGEST

The United States is by far the greatest user of non-energy minerals and other materials. The Nation is not and could not easily be self-sufficient for many materials. Each year it becomes more dependent upon imports. For some materials--chromium, tin, and manganese--it is already essentially 100 percent dependent on foreign sources.

This increasing dependence has given rise to anxieties and led to establishment of the National Commission on Supplies and Shortages, consisting of representatives from the Congress, the Executive Branch, and private industry. The Commission has begun assessing the Nation's overall position and the adequacy of its institutions for dealing with materials issues.

Because successful materials-oriented research and development (R&D) could increase the Nation's ability to deal with materials problems, the Senate members of the Commission--Senators John Tunney and William Brock--asked GAO to:

--analyze Federal funding for materials R&D, and

--evaluate the effectiveness of Federal materials R&D.

GAO's analysis led it to conclude that an adequate response to the request could only be made in the context of clear national materials policy goals against which the effectiveness of related R&D activities can be measured and with adequate data on the extent and current status of such activities. Early in its analysis GAO determined that neither of these exists. GAO, therefore, turned its attention to the basic steps required to provide (1) an institutional framework for developing materials policy goals and (2) the data necessary to adequately assess the contribution of materials R&D to accomplishment of the goals. (See pp. 5-6 and 36-40.)

KEY CONCLUSIONS AND FINDINGS

Institutional Capability

A national materials R&D program cannot be formulated without a definition of basic objectives of national materials policy. R&D efforts can then be directed to support policy objectives.

The overall goal should be the protection of the domestic economy.

In the short-run, this entails actions which will avoid or minimize the impact of severe shocks brought on by abrupt interruption in supply or rapid changes, particularly upward, in price. Long-run action should assure continuity of supply and minimize upward movements in materials prices. (See pp. 3-4.)

Currently, there is no system for assigning priorities to actions toward achieving national materials goals. There is no established institutional capability to assess alternatives and tradeoff considerations between potential actions. (See pp. 5-6.)

Despite changed and fluctuating circumstances, and increased need for continuing policy guidance, no appropriate institution has yet been devised. All that exists is an interagency committee lacking staff and authority to adjudicate differences between agencies and program options.

Federal Materials R&D

Research and development is not the solution to all material problems. R&D activity is appropriate only in relation to solving medium to long-range problems of material supply and efficient use.

R&D efforts can have major impact upon both demand and supply of individual materials commodities but, with rare exceptions, not in the short-term.

GAO's work highlights three aspects of past and present Federal materials R&D.

Program funding in constant dollars is actually decreasing:

While current dollar expenditures increased substantially between 1962 and 1974--from $185 million to to $331 million--growth in real terms (constant dollars) was only about 6 percent. Between 1969 and 1974, real expenditures declined from $249 million to $206 million, or by about 17 percent.

Implications of this decline cannot really be assessed in the absence of a policy framework. It cannot be demonstrated that more expenditures will give better results, nor is it possible to conclude that lower expenditures would be better. (See pp. 15-17.)

Federal R&D effort is highly fragmented:

There is no overall Federal materials R&D program. Rather, there exists a large number of specific mission-oriented R&D activities.

In fiscal year 1974 there were some 23 agencies with 90 subdivisions sponsoring materials R&D. It would be inappropriate to assume that the sum of these activities constitutes a viable national program. (See p. 21.)

Data is incomplete and poorly gathered:

Collection of R&D data over the last 15 years has been sporadic, incomplete, and insufficient for policy-making purposes. (See pp. 22-24, 41.)

Proper management of the R&D component of a national materials program is dependent upon a data-information system which facilitates the assessment of activities from various perspectives such as product category, sponsoring or performing organization, and phase of the materials cycle. (See p. 29.)

Phase of the materials cycle data has been urged since the 1973 report of the National Commission on Materials Policy. GAO determined that only the Smithsonian Science Information Exchange had existing capability to develop pertinent data. Using the incomplete information now in the Science Information Exchange, GAO developed for the first time data on materials R&D phase of the materials cycle. (See pp. 36-40.)

The Executive Branch Committee on Materials is engaged in the most serious effort to date to secure good financial and related data from all involved agencies. The Committee anticipates publishing an inventory of fiscal year 1976 Federal materials R&D activity before the end of calendar year 1975. If this inventory method proves workable, it may serve as a prototype for data collection upon which to base the needed expansion of the Science Information Exchange data bank. (See pp. 24-25, 43.)

Coordinated National Effort

Obviously, many elements outside the Federal Government are engaged in or supporting important materials R&D work.

Virtually no data on these efforts are available, however.

Federal and non-Federal materials R&D efforts should complement one another. Knowledge of the Federal effort only will not assure the most productive allocation of Federal resources. The Science Information Exchange can assist formulation of a balanced national program by seeking out the active cooperation of industry, trade associations, individual firms, independent R&D contractors and the university community. (See pp. 41-42, 44.)

GAO RECOMMENDATIONS

GAO made three recommendations aimed at modernizing the materials policy formulation process and the management of Federal materials R&D activity. (See pp. 48-49.)

First, the Congress should consider establishing an institution to analyze national materials issues and provide policy guidance on a continuing basis. GAO further recommended that the National Commission on Supplies and Shortages assign a high priority to fleshing out the details of the proposed institution and providing its input to the Congress.

At a minimum, the institution should have as basic responsibilities (1) analyzing policy options and tradeoff considerations, and (2) providing definitive guidance to operating agencies in planning for and executing materials policies, including materials R&D.

Second, a comprehensive unclassified information system for materials R&D should be established, building upon existing information in the Science Information Exchange. The Commission should work with the Executive Office of the President to obtain mandatory Federal agency participation in the system.

Third, the Science Information Exchange should include in its information system data pertaining to materials R&D outside the Federal Government. A properly balanced national materials R&D program cannot be developed without knowledge of activities underway in the private sector and university communities.

AGENCY COMMENTS

The Science Information Exchange agreed that its system could be used in the manner recommended by GAO. In preparing its final report GAO also obtained and considered the informed views of various Federal officials knowledgeable in matters of Federal materials R&D.

CHAPTER 1

MATERIALS, SHORTAGES, AND RESEARCH AND DEVELOPMENT

INTRODUCTION

Prior to the early 1950s, producers and consumers alike generally assumed supplies of materials, raw and processed, would be available to meet America's needs at reasonable prices. This assumption has been intermittently examined at the Federal level over the past 2 to 3 decades, especially as the country has become increasingly concerned over reliance upon foreign sources of materials.

These occasional examinations have not, however, induced any fundamental changes in either consumption patterns or assumptions regarding availability of supplies. Rather suddenly, a series of events culminating in the oil embargo and the administered price increases of 1973-75 shook general confidence in the Nation's ability to meet day-to-day needs for oil, steel, concrete, and almost all other materials.

The U.S. rate of materials use is prodigious. Americans constitute only about 6 percent of the world's population, yet they consume more than 30 percent of its energy and approximately 40 percent of its metals and other nonenergy minerals.1/

The present American lifestyle requires over 40,000 pounds of new materials annually for each citizen--20,500 pounds of nonmetallic materials, 17,300 pounds of mineral fuels, 1,340 pounds of metals, and 2,310 pounds of organics.2/ The United States has used more minerals and mineral fuels during the past 30 years than all the people of the world used previously.3/ If this use were to continue at the same rate, it would entail a further doubling of consumption by people now living in the United States through the remainder of their lifetimes.4/

The United States currently is dependent on foreign sources, in whole or in part, for approximately 22 of the 74 nonenergy mineral commodities considered by the Department of the Interior to be most essential to our industrialized economy.5/ It has been predicted that by 1985 the United States will depend on imports for as much as half of its supplies of basic raw materials.6/ It is already essentially 100 percent dependent on foreign sources for a number of materials--such as chromium, tin, and manganese--which are heavily used in current technology.

Concern over the nation's ability to meet material needs has given rise to an increasing number of questions, including:

--What should be the role and magnitude of materials research and development (R&D)?

--Can technology find a way?

--To what extend can R&D provide answers to materials requirements?

--Is the Federal materials R&D program operated in such a way as to assist in overcoming whatever long-run or short-run shortages may emerge?

PURPOSE OF REPORT

This report focuses on Federal materials R&D efforts and attempts to evaluate their organization in terms of their ability to meet national goals. This evaluation cannot be achieved in the abstract; i.e., without reference to a set of perspectives which shape the direction and scope of these R&D efforts. In other words, before the effectiveness of various Federal materials R&D activities can be appraised, it is necessary to supply answers to a series of separate questions.

The following seem to be the most urgent in terms of this examination:

--What should be the basic objectives of national materials policy?

--Does a system exist which assigns priorities to actions needed to achieve basic objectives?

--Has it become more difficult to attain the national materials goals in recent years?

--What alternatives are available to the Government to meet national materials supply problems?

--How does R&D fit into an overall approach toward meeting materials goals?

--What is an appropriate analytic framework for establishing materials R&D opportunities and priorities?

NATIONAL MATERIALS POLICY GOALS

What should be the basic objectives of national materials policy?

The materials goals discussed in this report are distilled from analyses contained in major studies of this area.7/ In addition, the identification of these goals has been assisted by a careful reading of pertinent testimony presented at congressional hearings and through extended discussions with other authorities vitally interested in the area. The actual goals enumerated, however, are largely unique to this report.

This independent articulation of goals is deemed necessary to establish the point that Government actions to avoid or ameliorate materials supply problems must have a dual focus related to timeframe considerations. Reviewing studies, etc., pertaining to materials supply issues reveals a failure to distinguish, in a consistent fashion, between short- and long-run goals, problems, and solutions. The time element, however, is crucial for both the feasibility and the desirability of various governmental actions. For example, R&D efforts would be largely ineffective in dealing with short-term problems. Conversely, economic stockpiling appears to be an unsuitable means of coping with long-term problems, since acquisition and storage costs of supplies sufficient to meet long-term needs would be prohibitive.

In the short-run, the basic goal is to minimize the impact of severe shocks to the economic system. Rapid changes (increases in demand and/or decrease in supply) usually bring substantial and abrupt increases in price, dislocation of output, and a reduction in employment--to list but a few of the possible adverse effects of such changes.

Recent rapid rises in oil prices illustrate concern over short-run price changes and resulting system instability. In general, short-run changes in the demand for oil products are not responsive to changes in price. For example, oil price increases are reflected in a far less than proportionate reduction in oil consumption. Rather they are felt in a reallocation of consumer expenditures away from other goods in favor of continued purchases of oil products. Therefore, while oil producers are benefitted by price increases, producers and consumers of other products experience a reduction in their total level of welfare. Rapid price changes introduce an important element of price instability where demand is price inelastic. The situation is aggravated in product areas where supply is inelastic also. Both conditions often exist in raw material areas characterized as being in short supply.

Adverse price behavior can upset consumer and producer expectations as well as decisions to invest and consume. Beyond the problem of stability and employment is that of equity. Adverse price behavior does not affect all sectors equally. Major sectors--those on fixed incomes, those holding debt obligations, and small firms with limited capital reserves--bear a disproportionate burden when faced with an unanticipated inflation. The adverse income distribution effects of inflation set off pressures for redress which can magnify the destabilizing effects of the initial shock.

Governments typically seek to deal with unanticipated commodity shortages; the United States is no exception. Recent U.S. actions have included decisions to draw down stockpiles of various commodities, to limit exports, to suspend import duties, and to allocate consumption. To date, however, the U.S. Government has been slow to adopt direct government-to-government negotiations as a means for coping with short-term materials problems.

One of our recent studies reviewed several of these U.S. actions and questioned their effectiveness and cohesion.8/ Concern along these lines continues as new proposals are considered (involving, most notably, expanded stockpiling), new agencies are formed, and old ones are revamped. The nation is still reacting to the embargo and related shocks of the early 1970s.

In the long-run, primary emphasis should be given to maximizing the surety of supply flows and minimizing the overall level of prices. Actual or impending scarcity of particular resources will lead to price rises and consequent incentives to obtain economies in consumption and to substitute plentiful resources for scarce ones. However, it is not at all clear that an advanced complex economy will adapt to a changing situation in the best manner nor that the full range of opportunities for adaption will be surveyed with equal care. This is significant since the economic welfare of consuming economies will be injured if it becomes necessary to devote an increasing proportion of limited capital and labor resources to sustain basic raw material inputs.

Though concerns about the long-term viability of resource supplies are expressed in many quarters and addressed by varying policy actions, many argue that the country lacks an adequate institutional mechanism for achieving long-run goals. Solutions to most materials problems simply have been left to the private sector. Price and profit have been assumed to be the only balance wheels of adjustment needed for materials procurement, despite the obvious shift from domestic self-sufficiency to foreign dependence for a widening array of commodities.

Does a system exist which assigns priorities to actions needed to achieve basic objectives?

Much past governmental policy has promoted the development of domestic supply capacity. Some recent steps have been taken to examine other aspects of materials use, particularly in the light of heightened concern over adverse environmental effects and rising energy costs. Although groups endowed with the authority to make such decisions exists (the Domestic Council and the Economic Policy Board), the nation has not achieved the development of an integrated materials resource policy designed to serve both our short-term and long-term objectives of system stability, minimum attainable prices, and surety of supply. It likewise lacks the institutional capacity to assess national materials policy in the light of national security and foreign policy objectives.

The establishment of a set of priorities for various national goals creates a corresponding set of problems. All goals cannot be classified as having the highest priority. A rational selection process involves an appraisal of relative gains and costs associated with the adoption of certain goals. Thus, efforts to select the highest priority items involve a corresponding ability to assess gains and losses. This process involves a "trade-off" analysis of various activities and assumes that it is possible to determine objectively that one action is better than another on the basis that the gain from doing the highest priority action is greater than the costs of not completing some other action.

Three examples of current interest may serve to enhance an understanding of this process. First, what should be the nation's posture with respect to alternative sources of iron ore? On the one hand, adherents of the "fortress America" approach might recommend that, in order to obtain an assured iron ore supply, U.S. deposits should be mined at any cost. On the other hand, cheaper iron ore can be obtained from foreign countries at the price of (1) engaging in foreign trade with possible balance of payments problems and (2) a possible shutoff in raw materials. A determination of the relative advantages and disadvantages constitutes a form of trade-off analysis.

This type of issue is likely to recur frequently, especially if materials aqcuisition policy acquires a new dimension--income maintenance for developing countries who are exporters of raw materials. Developing nations are becoming increasingly insistent upon modifications to traditional producer-consumer relations with respect to raw materials supply, and the matter is already subject to international negotiations. At the same time, there is growing sentiment for the U.S. to expand its materials production base particularly through modified use of federally-controlled lands. This supply option entails, among other things, significant environmental implications. Clearly, the matter of which supply sources should be put to use has become a highly complex issue which will require continuing assessment and evalution of available choices.

A third example deals with a controversy in the timber industry. On the one hand, an ostensible shortage of softwood sawtimber is held largely responsible for rampant price escalation in recent years. On the other hand, an upturn in exports of logs to Japan has improved the national balance of payments. At the present time, however, the exports may be aggrevating short-term domestic price problems. Again, rational trade-off analysis of policy options is required.

The development of a truly national set of goals requires that a simultaneous weighting process be established which will insure that maximum gains are achieved from those policies which are selected. This process requires an institution to assign weights and priority to various undertakings. In essence, evaluation of materials policy issues is a "hollow triangle" process. At the base, information is fed in by a variety of agencies. At the apex exists a decisionmaking capability--for example, the Domestic Council or the Economic Policy Board. What is lacking is an instutional capability, transcending individual agency concerns, for (1) continuously monitoring all aspects of the materials supply problem (2) anticipating issues requiring policy decisions,and (3) accomplishing necessary analysis of alternatives in timely fashion. In the absence of a permanent institution decisionmakers are likely to rely on an information "force-feeding" process whereby issues reach the top on a random basis. Present arrangements prevent decisionmakers from having both complete and timely analysis.

Has it become more difficult to attain the national materials goals in recent years?

Undoubtedly the nation has become more vulnerable to the destablizing influences of both short- and long-term shifts in materials availability. This increased vulnerability is basically a function of three major factors:

--In a substantial number of areas, domestic supplies of relatively cheap and readily available materials supplies have been consumed. Barring the unlikely discovery of substantial new domestic deposits of copper, lead, iron ore, silver, and petroleum--to name but a few--continued production depends upon the development of newer, cheaper processes for using remaining lower grade U.S. resources or expanding foreign supply sources.

--Over the past 1 to 2 decades the traditional goal of economic sufficiency has been expanded to encompass a consideration of environmental factors. Minimum cost, in a product sense, must be weighed against the environmental impact of any materials expansion program. Taking environmental costs into account may have the effect of reducing domestic materials output. This could in turn raise prices and alter the consumption potential of different sectors of the society.

--The United States is encountering an upsurge in potential for international supply interruption activities. The decline in U.S. domestic raw materials supplies coupled with our increasing foreign dependence has intensified U.S. vulnerability to actions by foreign governments. The Jamaican bauxite tax of 1974 and the oil embargo illustrates this vulnerability.

What alternatives are available to the Government to meet the nation's materials supply problems?

The effectiveness of a materials supply system is obviously partly related to physical considerations of availability. However, equally important are economic, political, and technical factors. Effective materials policy must simultaneously be in tune with each of these factors if materials supply and use are to be optimized.

The basic governmental role is one which seeks to compensate for the deficiencies of the price system. "There are good economic reasons for believing that the unaided price system is unlikely to function perfectly so there is room for public policy."9/ Professor Robert A. Solow of the Massachusetts Institute of Technology has identified three key areas of deficiency:

--Markets for resources tend not to be competitive in the usual sense of the word. They are dominated by a few firms.

--Competitive markets are complicated and cannot function properly when data is inaccurate or where participants try to mislead each other as to the "real" nature of their actions. A key element of competition is the presence of futures markets. In the absence of such institutional arrangements, there is no good way for the price system to register information and expections about the future.

--Technological and economic research is an important part of the market adaptive process.

> "But the private market is likely to generate too little research, especially basic research. . . . Knowledge should be shared because it is not used up by being used. In other words, research is a public good. . . . . that probably means increased Federal finance of research in the natural resource field* * *." 10/

A recent Arthur D. Little study, "Material Shortage Study: An Analysis of Selected Commodities and Identification of Causal Factors Contributing to Supply Shortfalls", states that the actions of government can either help or hinder with respect to materials supply problems.11/ It lists activities by the Federal Government as being among the most serious problems which limit the supply of materials to firms in the United States.

The A.D. Little report argues that price controls are probably the action which most retards domestic expansion. This argument assumes that domestic capacity would expand to meet demand if only profits were large enough. It is true that high prices and profits will stimulate the production of minerals found to exist throughout the earth's crust (i.e., iron and aluminum). The same argument cannot be used, however, to support a correlation between profitability and increased outputs of materials which can be found only in random, sharply bounded deposits (i.e., mercury and silver.) 12/

In spite of its restricted validity, the A.D. Little argument is used as an attack on a number of Government programs in addition to price controls. These include environmental regulations, tax policy, depreciation policy, anti-trust prosecution, and others.

While many assertions are made that Government activities tend to restrict supplies, the Government is also engaged in a number of programs which tend to increase the stock of materials and/or extend the lifespan of reserves known to exist. The bulk of these activities fall into four basic areas: conservation, stockpiling, promotion of international commodity arrangements, and promotion of research and development programs. Given the fact that resources are limited, tradeoffs between different programs must be evaluated.

How does R&D fit into an overall approach toward meeting national materials goals?

It is generally recognized that technical advance has contributed to the Nation's posting of sustained commercial growth. Federal R&D can contribute to advancements consistent with national materials goals. How Federal R&D expenditures are distributed is, therefore, an important consideration. R&D, however, is not the solution to all materials shortage problems.

New developments in recycling and solid waste treatment and the development of new substitutes may increase the degree to which materials self-sufficiency may be obtained. The discovery of new materials or combinations of old materials may vastly improve the performance of many products and production processes.

The manner in which materials R&D can contribute to sustained development has been explored by various studies. As long ago as 1952, the Paley Commission identified an array of specific materials R&D concerns.13/ The Commission listed six specific areas of primary importance. It pointed out that it was necessary to:

--Foster new techniques for discovery.

--Develop uses for materials (including solid wastes) that have defied previous efforts to use them.

-- Expand the role of recycling.

-- Maximize opportunities for use of low concentration ores in production processes.

--Use more efficiently renewable resources.

--Substitute abundant for scarce material wherever possible.

These same points, which have demand as well as supply implications, have been cited by several subsequent studies. A seventh area should be added to that list, however, if efficient resource management is to be achieved. Specifically, efforts should be intensified to lengthen the effective,useful life of products through improved technology and elimination of production characteristics which cause premature product obsolescence.

The development of a national materials R&D policy based upon these seven points of atack would go far towards maximizing the technological component of a solution of basic raw materials problems.

<u>What is an appropriate analytic framework for establishing materials R&D opportunities and priorities?</u>

A careful review of the major studies cited above (see footnote 7) reveals significant differences with regard to the types of materials focused upon, the time period covered by review, the conclusions as to areas of concern, and the implications for public policy. Such differences make it difficult to understand core issues in the materials R&D policy field. Even in the context of a single study, it is not necessary to search far to encounter complexity. For example, the National Commission on Materials Policy study presented a summary of recommendations which included 198 separate proposals.

One common theme of these studies, however, is the need for an integrated system for describing and monitoring materials R&D activity. These reports have regularly pointed out the necessity for coordinating broad areas of work across narrow agency lines of authority. A simple example may illustrate this approach.

A framework for anticipating potential problems and analyzing possible solutions to them requires the identification of (1) the specific material involved and (2) the particular attributes (restricted supply, availability of transportation systems, etc.) surrounding the supply and use of that material. Assume that a shortage of aluminum is projected. If this problem is to be solved, a number of actions should be attempted in a coordinated manner. The following stages are presented individually for the sake of clarity of exposition but not as part of any attempt to order them in terms of relative importance:

--Increase efforts that will expand the number of sources or which will utilize resources previously unused.

--Adopt programs which will reduce the need for aluminum or which will place stress upon efforts to develop substitutes for aluminum.

--Reduce costs of transporting fuels and bauxite for reduction to aluminum.

--Attempt to increase imports of aluminum instead of bauxite.

--Develop a process for extracting aluminum from aluminium-bearing clay.

--Modify environmental considerations so as to maximize production consistent with minimum environmental dislocation.

This is not a full list of actions and programs which could be undertaken to further the goal of increasing our usuable supplies of aluminum. The essential aspect of the list, however, is to show that what are now treated as a series of separate and and uncoordinated programs are in fact simply parts of one large problem--aluminum sufficiency.

Figure 1. ALUMINUM SUFFICIENCY

Programs or Projects	Disciplines				
	Social Sciences	Engineering	Envi-ronmental	Logistics	Economic
Discover New Sources					
Substitutes Research					
Aluminum Clay					
Transpor-tation Problems					
Minimizing Smeltering/ Refining Costs					
Imports of Aluminum					

Eugene Fubini insists that agencies and individuals must forego what he calls the American Matrix approach wherein each boxed item in the above input-output table is treated as a separate problem instead of recognizing explicitly that all the items are interrelated.14/

A potentially significant, new methodology for assisting development of comprehensive materials research strategies has recently been reported by Ivars Gutmanis and Richard McKenna of the National Planning Association.15/ Further, as shown in the next chapter, some experience has previously been gained in the materials field in the formulation of integrated research strategies. The next chapter shows mainly,however, that the present situation--where individual agency R&D projects and activities are determined separately--is basically inconsistent with a coordinated management process for Federal materials R&D.

CHAPTER 2

AN APPRAISAL OF FEDERAL MATERIALS R&D MANAGEMENT

Although studies appearing since 1952 have detailed actual and potential material problems, growth in general perception has been slow. Little serious attention was directed to the problem of materials interruption prior to the 1973 embargo of petroleum. This event generated concerns over the possibility of disruptions occurring in other material areas.

Since 1973, many analysts have shifted their position vis-a-vis shortages of all materials from that of the complete optimist--one who believes that technology will provide a solution to every problem that nature offers--to that of the complete pessimist who, according to Robert Solow:

> "***will ignore all such possibilities (new discoveries, etc.) and be obsessd with the simple arithmetic, observing that if you keep ladling soup out of a bowl you eventually hit bottom - without ever wondering seriously if earth is quite like a bowl of soup and the economic process quite like a ladle."1/

Regardless of the nature of the problem, materials availability is a matter of considerable concern. With this goes a high degree of faith that many of the problems can be solved by research and development.

OVERALL FEDERAL R&D PROGRAMS

Over the past 15 years the trend of overall levels of Government-sponsored research and development expenditures has taken a substantial change in direction, particularly in relative terms. Between 1953 and 1965 Federal R&D funding increased steadily from $2.8 billion to $14.9 billion; it fell slightly, however, in 1969 and 1970. Expenditures then increased from $14.8 billion in 1970 to an estimated $20.2 billion in fiscal year 1975.

As the data in table 1 shows, Federal R&D expenditures, on a current dollar basis, more than doubled--going up 118 percent--between 1961 and 1975. Almost 40 percent of that increase occurred between 1971 and 1975. However, while total current dollar Federal R&D expenditures increased, the proportion of the Federal budget allocated to R&D steadily declined from 12.6 percent in 1965 to 6.6 percent in 1975. Moreover, the Federal budget allocation to R&D has declined a striking 31 percent in terms of constant dollars between 1967, its peak year, and 1975.

TABLE 1

Estimates of Total Federal R&D Expenditures
1961-1975 (Selected Fiscal Years)
(in billions)

Fiscal year	Current dollars	Constant dollars (note a)	Expenditures as percent of total Budget outlay
1961	$ 9.3	$ 9.8	9.5
1963	12.0	12.7	10.8
1965	14.9	15.4	12.6
1967	16.9	16.9	10.7
1968	17.0	16.6	9.5
1969	16.4	15.4	8.9
1970	15.7	14.3	8.0
1971	16.0	14.0	7.6
1972	16.7	14.1	7.2
1973	17.5	13.0	7.1
1974 (est.)	18.6	11.6	6.7
1975 (est.)	20.2	11.6	6.6

Source: National Science Foundation, "Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1973, 1974, and 1975," vol. XXIII, apps. C and D, table C-108 (1974), p. 144.

[a] 1967=100

For the last decades, Federal R&D activity hs been dominated by defense and/or space-related projects. In 1969, this sector accounted for some 77 percent of the total activity. By 1975 it had declined but it is still equal to 65 percent of the total Federal R&D obligations (table 2). During this same period, Federal R&D spending on other types of programs grew in both relative and absolute terms.

Table 2

NATIONAL SCIENCE FOUNDATION DATA

Summary of Total Federal R&D by Functions
FY 1975

Function	Percent of Federal R&D expenditures
National defense	52.2
Space	13.0
Health	10.0
Energy development & conservation	5.1
Environment	5.0
Science and technology base	3.9
Transportation & communication	3.6
Education	1.1
Income security & social services	0.7
Community development	0.7
Economic growth & productivity	0.6
Crime prevention & control	0.3
International cooperation & development	0.2
	100.0

Source: National Science Foundation, "An Analysis of Federal R&D Funding by Function," Aug. 1974, p. 2.

MATERIALS R&D FUNDING

A limited quantity of information pertaining to total Federal R&D is available in National Science Foundation publications. 2/ However, little data is available which deals directly with materials R&D activity.

As far as materials R&D is concerned, the data in table 3 shows that it has had a constant but only tiny share of total R&D, averaging less than 2 percent annually since 1962.

The first set of statistical data pertaining to materials R&D became available in a 1964 report of the Coordinating Committee on Materials Research and Development. 3/ That report summarized Federal materials R&D expenditures into five product categories for fiscal years, 1962, 1963, and 1964. In 1971, the Interagency Council for Materials published a followup study containing similar but not identical data for the period of 1965-1971. 4/ Early in 1975, the Federal Council for Science and Technology published a report

Table 3

Estimates of Total Materials R&D Expenditures
(in millions per fiscal year)

	Coordinating Committee On Materials Research and Development (note a)			Interagency Council for Materials (note b)			SSIE (note c)	Federal Council for Science and Technology (note d)
	1962	1963	(Budget) 1964	1967	1969	1971	(Estimated) 1974	(Estimated) 1976
Current dollars	$184.8	$214.8	$220.5	$242.1	$264.8	$254.9	$330.6	$470.0
Constant dollars (1967 = 100)	$194.9	$226.2	$232.8	$242.1	$248.6	$223.8	$206.5	n.a.
Percentage of Total R&D Expenditures (National Science Foundation)	1.8	1.8	1.5	1.4	1.6	1.7	1.8	2.2

Source: [a]Coordinating Committee on Material Research and Development, CCMRD Survey of Federal Directly Supported Research and Development, May 1964, page 5.

[b]Interagency Council for Materials, ICM Funding Survey of Federal Directly Supported Materials R&D, August 1971, Table 1, page 1.

[c]Special Tabulation of Smithsonian Science Information Exchange.

[d]Federal Council for Science and Technology, Report on the Federal R&D Programs FY 1976, page 124.

which projected Federal materials R&D expenditures for fiscal year 1976. 5/ These data are summarized, along with fiscal year 1974 data contained in the files of the Smithsonian Science Information Exchange (SSIE), in table 3.

This data shows that between fiscal years 1962 and 1974 current dollar extimates of Federal materials R&D expenditures grew from $185 million to $331 million annually--an increase of roughly 79 percent. However, when the data is adjusted to compensate for the effects of inflation, it shows that Federal materials R&D declined by about 17 percent between 1969 and 1974. In constant dollar terms, 1974 expenditures were at their lowest level since 1962.

The implications of this decline cannot really be assessed in the absence of a policy framework. It cannot be demonstrated that more expenditures will give better results, nor is it possible to conclude that lower expenditures would be better.

PAST EFFORTS TO ESTABLISH A COHERENT FEDERAL MATERIALS R&D INFORMATION SYSTEM

In the 1960s, there emerged a slowly rising level of awareness of the need for the development of information showing the size, scope, and direction of Federal R&D activity in the materials sector. The first manifestation of this concern was the establishment of a Committee on Materials in 1963 within the Federal Council on Science and Technology. This organization became the Coordinating Committee on Materials Research and Development. The founders of the Coordinating Committee were specifically concerned with (1) where Federal R&D money was being spent, (2) who was spending it, (3) possible gaps which might exist between the agency programs, and (4) the need for a forum where agency representatives could meet and explore problems which they felt to be of paramount importance. In essence, they wanted to look at future problems and areas of accomplishment, not just at past and present problems and their solutions.

Despite this conception, the Coordinating Committee was limited in approach. First, it had a strong basic science orientation with little or no engineering or other input. Second, it was composed of representatives of only selected agencies, including the Atomic Energy Commission, the Department of Defense, the National Aeronautics and Space Administration, the National Bureau of Standards, and the Bureau of Mines. Third, the representatives were at the chief-scientist level; consequently, they were not active in policy determination. Finally the Coordinating Committee operated entirely with borrowed staff.

It began a series of reports. However, only one of its reports dealing with R&D expenditures, was actually published. 6/ Data from it are presented on page 22 (table 4). A second report was begun which looked at existing problems and opportunities which the Coordinating Committee members felt should be exploited. A third report was begun which involved the development of a matrix of opportunities and agencies which might provide solutions for each problem area. It was to have been composed of case studies and was designed to develop and cost programs on a systemwide basis. Areas selected for analysis included housing, corrosion, and biomaterials. These studies were not completed. As one member of the Coordinating Committee put it, "the programs were stopped in a morass of red tape and died for lack of a sponsor." 7/ Not only did the program die--the Coordinating Committee died also.

In its brief 5-to 6-year history it had made an indelible mark, however. It had identified significant program and problem areas, suggested approaches to their solution, and developed methods to cost programs.

Finally, it identified an administrative approach which might be followed--the creation of the lead agency concept for providing guidance and coordinating efforts in R&D activity in individual, specific material sectors. The lead agency would be given primary responsibility for monitoring and coordinating research in a specific problem area. It would formulate programs consistent with the analytic framework presented in chapter 1 to meet obvious problems and encourage others to participate in a coordinated R&D program. It would not, however, have direct control over the R&D programs of other contributing agencies.

Despite the abolition of the Coordinating Committee, concerns remained regarding the management of materials R&D. In response to this perception, in 1969 the Science Advisor to the President established a task force to answer a number of questions. First, did a need exist for a management coordination group? Second, if yes, what kind of an organization should be set up? Third, what should its charter be? Fourth, who should participate in the group?

The task force agreed that there was a need for a materials coordinating mechanism and that it should involve representatives of all agencies conducting materials research programs. 8/ Moreover, the group should monitor and recommend action but not manage individual agency programs. The task force suggested that the group be set up in a nonoperating, bias-free environment. In line with this, it suggested three alternative organizational forms that might be used. First, the program might be under the control of an agency like the

Federal Council on Science and Technology but with a staff. Second, program coordination might be accomplished through a single lead agency. Third, a group might be established within the National Materials Advisory Board of the National Academy of Science. The last option was adopted and the Interagency Council for Materials came into being in January 1970.

Two basic differences existed between the Coordinating Committee and the Interagency Council. First, responsibility for materials R&D coordination was transferred out of the Office of the Special Assistant to the President for Science and Technology to the National Academy of Science. It was anticipated that this change would enhance coordination between the Federal and private sectors. Second, the Interagency Council was to be a more policy-oriented group. Agencies were contacted at the Assistant Seceretary level and asked to send senior representatives involved in materials policy issues. 9/ Eleven agencies were contacted. Nine of these were active participants in that they provided minimal funding assistance--$5,000 each. With this money an administrator and a secretary were employed. 10/ The Chairman was selected internally and the Chairmanship rotated annually.

The first report of the Interagency Council listed its objectives as:

--Providing a forum for discussion of major problems and the possible development of remedies through cooperative Government activities.

--Examining the total Federal materials effort and assessing the adequacy of basic and applied R&D to meet immediate and long-range needs.

--Evaluating specific areas of research initiated in support of some urgent national goal.

--Identifying national materials technology gaps and manpower requirements in the light of changing national objectives to maintain a high level of resource competence to meet future needs. 11/

The Interagency Council had an even shorter life than the Coordinating Committee. The Executive Office of the President failed to exhibit any real interest in this area. After 1 year of operation, 1971-1972, a decision was made not to ask for further funds and the operation of the Council ended in 1973.

No one felt strongly enough to take this program on as a major or leading task. Why was this so? First, the location of the Interagency Council for Materials in the National Academy of Sciences proved to be inconsistent with the basic National Academy mode of operation. Second, as one member of both groups said, it appears that, in Executive agencies, "Materials were not perceived as being a high priority program at that time." 12/

In 1975 yet another Federal interagency committee was established--the Committee on Materials which reports to the Federal Council for Science and Technology. Composed of high-level administrators from some 15 agencies, the Committee on Materials held its first meeting in May 1975. the Committee's stated goals are similar to those of its predecessor, the Interagency Council.

--Provide a forum for the discussion of major materials problems and for implementing remedies through cooperative Government activities.

--Examine the total Federal materials effort to assess the adequacy of the basic and applied R&D to meet immediate and long-range national needs and to affect coordination of the total materials effort within the Government.

--Evaluate specific areas of research initiated in support of urgent national goals and initiate coordinated programs when required.

--Identify national materials technology gaps and manpower requirements in relation to diverse and changing national objectives. 13/

Despite the fact that the Committee on Materials is another interagency committee, it exhibits some differences in approach from previous efforts. First, it involves representation at the Assistant Secretary level, improving chances for pertinent policy guidance to materials R&D activity. Second its perspective is broader, revealing concern for the "total cycle" of materials usage. Third, it appears to be more output oriented than its predecessors. It is divided into three task forces, one of which is engaged in a detailed inventory of fiscal year 1976 materials R&D activity. This inventory effort could lead to better methods for collecting and presenting R&D data. However, even while the Committee may function more successfully than predecessor committees, such an interagency organization is not a substitute for a permanent institutional capability of the nature described in chapter 1.

CHARACTERISTICS OF MATERIALS R&D EFFORT

Beyond the funding decline already noted, past and present Federal materials R&D efforts appear to have two other outstanding characteristics. The first is fragmention of effort. The second is statistical summarizations which focus on only quite broad product categories.

Fragmentation

The U.S. approach to materials research and development is highly fragmented. The available data suggest that there are at lease some 23 Federal Agencies, through some 90 different subdivisions, engaged in funding materials R&D programs. (See apps. II and III) Four points warrant attention

-- Most of the traditional big R&D spenders (Department of Defense, National Aeronautics and Space Administration, and Energy Research and Development Administration) are not primarily engaged in R&D programs aimed at identifying and/or alleviating broad materials problems. A synthesis of comments by agency officials we interviewed in 1974 indicated that their programs:

> "***have not been directed towards research on materials because they are of a crucial or strategic nature or because of a possible shortage. These considerations had no effect on establishing priorities in the past; however, they may be considered in future planning."14/

-- Most agencies are highly mission oriented. As a consequence, they appear to have had no strong interest in assuming general responsibilities beyond their primary mission. In fact, in the past, they might well have been severely criticized had they attempted to expand their R&D programs. The potential for such criticism, valid or not, continues to exist.

--In general, agencies have not been given any basic responsibilities for conducting or coordinating research for defined components of a national materials R&D program.

--The sheer multiplicity of agencies in materials R&D gives rise to concern regarding research overlap and redundancy. At least as important as concern over potential "waste" is that the absence of effective coordination may permit important gaps to develop and fail to be observed or corrected within the overall materials R&D effort.

Statistical Summarizations

A major characteristic of past statistical summarizations of materials R&D has been an effort to portray federally-sponsored activity by type of materials--usually according to quite broad product categories.

Coordinating Committee on Materials Research and Development

The earliest study referred to contained incomplete estimates submitted to the Coordinating Committee by various agencies (table 4) of Federal materials R&D expenditures. "The Committee estimates that this compilation includes less than half the total Federal materials program."15/

Table 4

Estimates of R&D Expenditures by Type of Material
(in millions)

Category	FY 1962	FY 1963	(Budget) FY 1964
Metals & alloys	$ 93.8	$108.5	$103.0
Organic solids	17.1	21.1	24.9
Inorganic non-metallics	62.0	72.5	77.1
Composites	4.1	4.4	9.0
Other	7.8	8.3	6.5
Totals	$184.8	$214.8	$220.5

Source: Coordinating Committee on Material Research and Development, "CCMRD Survey of Federal Directly Supported Research and Development," May 1964, table 1, P. T-1

The largest of these, "metals and alloys," accounted for about 50 percent of the total between 1962 and 1964. The second largest category, "inorganic nonmetallics," accounted for about one-third of the total.

Interagency Council for Materials

The Council report, which employed a data collection program like that of the Coordinating Committee, contained data similar to the Committee product groupings for the period 1967-71. The Council report did not compare categories. 16/

Table 5

Estimates of Expenditures by Type of Material
(in millions)

Category	FY 1967	FY 1969	FY 1971
Metallic materials	$ 97.4	$104.1	$ 97.6
Organic materials	50.4	53.9	53.6
Inorganic non-Metallics	58.6	66.7	61.9
Composite materials	21.0	25.0	25.9
Fuels, lubes, fluids	6.0	5.3	5.3
Other	14.7	15.2	15.9
Totals	$248.1	$270.2	$260.2

Source: Interagency Council for Materials, "ICM Funding Survey of Federal Directly Supported Materials R&D," Aug. 1971, table 1, p. 1.

In 1967, 1969, and 1971, "metallic materials" R&D expenditures continued to be the largest category. The share accounted for by this category declined from about 50 percent in 1964 to less than 40 percent in 1971. R&D expenditures, for "composite materials" experienced rapid growth, moving from slightly over 2 percent in 1962 to about 10 percent in 1971. A similar increase is apparent in the "organic solids" area. In 1962, this category accounted for slightly less than 10 percent of total materials R&D; by 1971, it accounted for about 20 percent of Federal R&D expenditures.

Federal Council for Science and Technology

The Federal Council data estimates (table 6) shows an anticipated total of $476 million for materials R&D expenditures in 1976. The Federal Council report utilizes some material categories, but its classification system departs substantially from the earlier reports.17/ The information presented on materials R&D is not comparable because of the indeterminant nature of the classification system and the aggregated nature of the data. However, the Federal Council report represents a first effort to collect comprehensive data which describes agency R&D activities by program and work area. Moreover, it attempts to organize R&D activity information on a basis which makes it more usable for policy formulation. In these respects, therefore, it represented a step forward in presentation of materials R&D data.

Table 6

Estimates of Fiscal Year 1976 Expenditures by Categories of Materials R&D (in millions)

Category (note a)	Expenditures	Percent of total dollars
Materials supply	$112.3	23.6
Materials utilization	265.7	55.8
Materials structures, properties, and performance	80.0	16.6
Materials-associated R&D: Environmental and health effects	18.0	4.0
Totals	$476.0	100.0

Source: Federal Council for Science and Technology, "Report on the Federal R&D Program FY 1976," p. 124-133, 135.

[a] These categories are described in the report.

Committee on Materials

The budget estimates of materials R&D activity for fiscal year 1976 by the Committee have not yet been published. Despite this it is worthwhile to note the refinements that have been made by the Committee in the detail which its report will include. Data will be reported under Federal Council for Science and Technology categories, categorical missions, and materials classes.

A. Federal Council for Science and Technology
   1. Materials supply
   2. Materials utilization
   3. Resource recovery from waste
   4. Materials structure, properties, and performance
   5. Materials--associated R&D

B. Categorical missions
   1. Communication and sensing
   2 Transportation
   3. Space
   4. Energy
   5. Environmental quality
   6. Health
   7. Safety
   8. Construction
   9. Production Equipment
   10. Consumer goods
   11. Resource development, supply and conservation
   12. Security
   13. Defense
   14. Process development
   15. Education and basic research
   16. Other

C. Materials classes
   1. Ores and minerals
   2. Metals
   3. Rocks and stone
   4. Ceramics
   5. Glass
   6. Inorganic chemicals
   7. Gases
   8. Composites
   9. Fossil hydrocarbons
   10. Organic chemicals
   11. Plastics
   12. Silviculture products
   13. Agriculture products
   14. Animal products
   15. Wood
   16. Paper
   17. Rubber
   18. Fibers
   19. Fertilizers
   20. Water
   21. Waste
   22. Contaminants
   23. Scrap
   24. Other

> "In addition to classes, a keyword method of information retrieval will be established to provide program description capability relating to specific materials, such as ferro chromium, ethylene glycol, sialon, etc." 18/

THE NEED FOR AN EXPANDED DATA BASE

The data presented in tables 4 and 5 portrays total materials R&D expenditures by broad class of materials. The Federal Council for Science and Technology material (table 6) provides additional insight in that it looks at actions associated with the R&D activities that are undertaken rather than placing sole emphasis on materials. This latter classification represents an acknowledgment that contemporary and future materials problems are more complex than merely finding new supplies or searching for means of improving the properties of materials. The long-term program for meeting U.S. materials problems must consciously address all phases of what is generally called the materials cycle--exploration, extraction, processing, design, use and performance, recycling, and disposal--within the competitive international context described in the preceding chapter.

The most complete exposition of the value of viewing materials problems as a part of the evolution and operation of a cyclical "materials system" is contained in the 1973 National Commission on Materials Policy report.

The report describes the "closed" materials system in the following way:

> "Materials move from resources in the ground to the pool of available supply. This supply phase of the system consumes energy to extract or harvest materials and process them for use. The sources of this energy, for the most part, are themselves materials, such fuels as coal, oil, or gas. These fuels are burned also in the use phase of the system, to run cars and heat and cool houses.
>
> "After purchase, materials except energy and some others which are dissipated remain in the use phase of varying lengths of time* * *.
>
> "Discarded material if not re-used is disposed of in open dumps, landfills, or the sea* * *.
>
> "Recycling makes the system circular and introduces a recovery phase.* * *.
>
> "The recovery phase, as a major component of the system, diminishes the role of disposition. An efficient materials system emphasizes land reclamation for mining wastes, technological control of air and water pollution, and collection and separation for discarded consumer goods. An enhanced environment and economics of energy and materials are major contributions of this system."19/

The National Commission on Materials Policy study makes a further observation upon the role of R&D within the context of a total materials system.

> ". . .The market translates consumer demand for goods and services to the producers. The demand for goods and services creates an indirect demand for materials based upon functions those materials can perform. The choice between several materials capable of performing the same function depends chiefly on their relative technical and economic efficiency and availability through established productive enterprise.
>
> "Capital equipment and engineering knowledge and skills are the end-products of research and development. Research and development improve the materials system by such activities as the discovery of new economically exploitable resources; new processes for extraction, refining, and fabrication; the development of new materials; new applications for old and new materials; and clean, pollution-minimizing technology."20/

The major phases of the materials cycle are in chapter 4 of the National Commission study: 4B discusses material supply; 4C, D, and E discuss, in order, material use, recovery, and disposal. Specific recommendations are made by material phase which bear upon the Federal materials R&D activity. To indicate the nature of these recommedations without an exhaustive discussion, representative recommendations are listed below for each of the major phases.

The authors of that report recommend that:

Supply

> "* * *the State and Federal Governments extend support to departments of earth sciences in institutions of higher learning which have attained excellance in this field. In particular, public officials should support research in methods of material exploration, mining engineering, metallurgy, and material sciences on the same scale considered wise for other, more visible, public needs."21/
>
> "* * *the Office of Management and Budget and other Government planning officials adjust the budgeted funds to expand the exploratory work of the U.S. Geological Survey and the Bureau of Mines* * *."22/

"* * *the Executive Branch of the Federal Government and the Congress develop and provide sustained support for a program to increase and extend timber supplies in the United States, including the following necessary actions:23/

--use of improved equipment and manufacturing processes.

--research and application of new technology in timber growing, in processing of timber products, in preserving wood against decay and insect damage, in consumer use of wood products, and recycling of use paper and solid wood materials."24/

Use

"* * *the Department of Commerce fund a comprehensive survey:

--to determine losses sustained in the United States from corrosion, friction and wear, fracture and high temperature service in the various industries, and to calculate the amount of savings that can be affected by application of established measures."25/

--to assess adequacy of present research in these fields and to fund additional research, if necessary.26/

--to recommend improved methods for dissemination of pertinent data."27/

Recovery

"* * *the Federal Government give users (scrap consumers, e.g., steel mills) of materials economic incentives in the form of tax credits for expanded use of recycled materials.28/

"* * *the Federal Government offer tax credit for investments in new plants and equipment specifically geared to the production of marketable products from recycled materials, with 5-year amortization deductions for companies that install ancillary equipment that will allow them to process larger quantities of scrap than at present."29/

"* * *the Federal Government accelerate research and development and technology transfer on resource recovery, especially to encourage recovery of resources in municipal wastes."30/

Disposal

"* * *industry develop and expand technology and markets that will allow for practical use of all bulk waste."31/

A major shortcoming of the National Commission study is that, notwithstanding its comprehensive scope, it failed to assign priorities or to suggest which of its recommendations should take precedence.32/ Consequently, it fails to provide guidance to policy makers in a "real" context. In all, it contained 22 pages of recommendations. If all of these could be implemented, there might not be a problem. This is not the case; resource limitations exist. Therefore, it is necessary to make trade-offs--to select alternative courses of action. The National Commission report did not make such suggestions.

CONCLUSIONS

An appraisal of the effectiveness of past and present R&D management must be couched in terms of the development of (1) an effective management approach and (2) a meaningful and usable information system.

The preceding discussion indicates that neither of these prerequisites exist. Management and research are fragmented, while the data which have been used are not responsive to the full range of concerns requiring analysis. The need is not simply to collect more data, but to insure that it exists in relevant form. A data system which is focused upon the collection of the "wrong" data is little better than no system at all. In some respects it may be worse since it may induce policymakers to place emphasis upon the "wrong" problems and, therefore, lead to a misallocation of resources.

CHAPTER 3

SSIE

Federal efforts directed at preventing or ameliorating problems of materials supply require continuing central policy direction. Wherever management responsibility is assigned for the R&D component of a coordinated Federal program, it must be accompanied by a viable information system. The SSIE program offers the most immediate opportunity for an effective, operational materials R&D information system.

DEVELOPMENT OF SSIE

The SSIE program began in 1949 as an informal arrangement among six medical research agencies. These agencies agreed to create and contribute to a cooperative clearinghouse for in-progress scientific research.

In 1953, the program was expanded to include all life sciences; in 1960, it was expanded to include physical and social sciences; and in 1964, the SSIE was designated as the center for cataloging current and projected research in all sectors of water resources research.

In 1963, the National Science Foundation was selected to assume the management and funding of SSIE. In 1972, SSIE's administrative and fiscal activities were transferred from the National Science Foundation to SSIE. SSIE is a nonprofit corporation controlled by the Smithsonian and receives about two-thirds of its support from Federal appropriations made through the Smithsonian.

SSIE is to be commended for the manner in which it has operated. Despite its efforts and diligence in seeking to expand its data base, the fact remains that its base is incomplete and that its program yields less meaningful data than would be anticipated if the program described in the "FY 1976 Budget" were realized in full. The appendix to the budget describes the scope and operation of the SSIE program as follows:

> "The Exchange gathers, synthesizes, packages, and delivers information on scientific research being conducted by the Federal Government and the private scientific community. It answers questions from research investigators, directors, and program

administrators throughout the national science community regarding who is currently working on what project, where, when, and source of funding.

"In addition to serving the scientific community, the Exchange has expanded its services to Federal, State, and local legislators and their staffs. Input of information on research supported by State and local governments has also increased in recent years. As a result of SSIE's role in a number of programs of key national interest, input on international, ongoing research has been increased in areas such as energy research, cancer research, pesticide research, etc. This information will be utilized by research managers and policymakers concerned with development of national programs and future international, cooperative efforts." 1/

NATURE OF DATA COLLECTED

The data collection forms presently used by SSIE are of a summary nature and do not include the data elements which are desirable for a materials R&D activity information system. Each reporting agency (93 in 1975) is supposed to file with SSIE a one-page "Notice of Research Project" for each project it undertakes or contracts for. This form contains the following pieces of information:

- --SSIE number.
- --Name of supporting agency.
- --Title of project.
- --Identification of principal investigators and department.
- --Agency identification number.
- --Address of performing organization.
- --Name of performing organization.
- --Time period covered by Notice of Research Project.
- --Funds to be expended.
- --Summary of project.

When this data is received by SSIE, it is put into the SSIE computer. In some cases, the forms are not filed with SSIE. Agencies submit to SSIE either hard-copy project forms or magnetic tapes containing the data on a biweekly, monthly, quarterly, or some other basis. Recent changes in the size of the program are shown in table 7.

Table 7

All R&D Projects Filed with SSIE
FY 1971-75

	Federal	Non-Federal	Total
1971	66,691	21,932	88,623
1972	67,756	18,439	86,195
a 1973	71,361	19,718	91,079
b 1974	96,353	22,890	d,e 119,243
c 1975	64,709	12,126	76,835

Source: SSIE, "Projects in SSIE Computer file by Federal Fiscal Year", Mmeo. Undated.

a Because of limited funds for data storage, summaries of research projects for 1973 and earlier years are presently available from microfilm files only. This severely restricts the useability of this data.

b The official estimates suggest that this data for 1974 was about 90-percent complete in July 1975.

c "Projects on tape as of May 30, 1975. This figure is expected to reach 130,000 for FY 1975 based on projects currently being processed into the system"--from an SSIE Mmeo. Returns estimated to be 50-percent complete.

d Includes roughly 10,200 social science (economics, urban studies, water resources, and other) projects.

e The substantial increase in reporting in FY 1974 is a function of two events: (1) efforts by SSIE to get controlling agencies to submit reports on a disaggregated basis which more nearly corresponds with the manner in which contracts are parcelled out and (2) SSIE appears to have obtained better agency reports with the passage of time.

PROGRAM COSTS

Despite the growth of the SSIE program it remains a relatively inexpensive one to operate. Budget appropriations for the SSIE program for the period 1972-76 are contained in table 8, but this data does not include the costs incurred by the agencies in submitting information to SSIE.

Table 8

Appropriation for SSIE Program (note a)

	FY 1972	FY 1974	FY 1975 (note b)	FY 1976 (note b)
	-------------(000 omitted)-------------			
Appropriation (note a)	$1,600	$1,695	$1,805	$1,875

Source: Office of Management and Budget, "The Budget of the United States Government Fiscal Years 1972, 1974, 1975, and 1976."

a In current dollars.

b Office of Management and Budget estimates.

This data shows that, compared to other data management programs, the SSIE program does not involve large, direct costs. 2/ For example, in no year thus far has its appropriation been as much as $1.9 million. Over the 12-year period between 1963 and 1975, the direct program costs were estimated to have totaled slightly less than $18 million. Between 1972 and 1974, the number of reports processed increased from 86,195 to 119,243 (an increase of 38.4 percent). During this same period, appropriations, in current dollars, increased from $1,600,000 to $1,695,000 (an increase of 5.9 percent). In constant dollars direct program costs declined significantly during this period.

One way of assessing the program's cost is to examine the cost per report processed. Officials of SSIE estimate that some 130,000 reports will be filed and processed for fiscal year 1975. Assuming that program costs will remain at $1,805,000, the average cost per report turns out to be about $13.88, down from $18.56 in 1972.

The low level of ...
limits its usefulness as a management or analytic tool from the standpoint of the analyses which we find to be necessary. For example, the fiscal year 1973 data has already been placed on microfilm for storage. With not all the 1974 and 1975 data received, the consequence is that data for the most recent complete year is unavailable in an easily accessible form. The basic reason given for this shift was that disc storage for the 1973 data would cost about $20,000 per year, and SSIE could not afford this. For lack of $20,000, these data have become accessible only at significant cost.

PROGRAM USE

The data submitted to and processed by SSIE can be used in a variety of ways. However, its quality depends upon the willingness of cooperating agencies to supply accurate, complete, and timely data.

The SSIE program is used most by agencies, companies, and individuals to search or cross-check the SSIE bank to determine whether or not a specific type of research is underway, is being contemplated, or has been conducted by others in the recent past. Two clear advantages appear here. First, this enables the researcher to avail himself of knowledge available elsewhere which may bear upon the area in which he is interested. Thus, recent work by others may be incorporated into some present or contemplated research. Second, research related to grant applications and the existing workloads of applicants can be reviewed. Before SSIE began charging for user services, the National Institutes of Health annually submitted search requests for more than 20,000 investigator names in connection with its grant application review process. This level of use by the National Institutes declined sharply, however, after charges were instituted in 1968.

The National Institutes have also used SSIE tabulations for trend and pattern analyses in the field of cancer therapy. Recently, a non-Federal organization asked SSIE to produce tabulations, limited trend analyses, and forecasts dealing with the organization's primary field of interest--agricultural chemicals.

A review of the SSIE activities in water resources research shows that the system can be usefully employed when it has a clearly defined assignment. Following passage of the Water Resources Research Act of 1964, Public Law 88-379, the President assigned SSIE the job of cataloging current and projected research even though the Department of the Interior remained responsible for overall administration of the act. Coordination has been close between SSIE and the Office of Water Research and Technology, Department of the Interior. SSIE described the coordination in the following manner:

"1. In Fiscal Year 1975, the Earth Sciences Branch responded to 161 requests for information on water resources research or related subjects. This amounted to more than half of the total requests in all fields handled by the branch during the same period. Some additional requests in the field of Water Resources were handled by other branches at SSIE. There are about 12,000 projects indexed to the Water Resources subject index.

2. Beginning in 1965, SSIE provided the Office of Water Research and Technology with annual catalogs of Water Resources Research. The latest SSIE output to date was for catalog #10 in 1975.

3. SSIE also supported the Office of Water Research and Technology's production of biweekly Selected Water Resources Abstracts by providing two editions of a Water Resources Thesaurus, the first in 1966, the second in 1971.

4. In 1973 and 1975, SSIE provided the material for the Office of Saline Water (Department of the Interior) Catalog of Research Projects.

5. In 1968 and 1975, SSIE prepared the Catalog of Marine Research." 3/

SSIE DATA DISPLAY

The presence of accessible past and present statistical data would make it possible to determine whether or not agencies are addressing themselves to priority goals. For example, the existence of an up-to-date information system should enable policymakers to review the direction and magnitude of R&D activity in total or in product category or material phase areas.

The potential of the SSIE program to serve as the basis for such a system is demonstrated by the following materials data which were developed by SSIE through a services-purchase contract with us. Even though the Final Report of the National Commission on Materials Policy stressed the need for data showing materials R&D activity by phases of the cycle, such compilations have not previously been made. We were the first to request SSIE to assemble materials R&D data in such a format.

Detailed data for 1974-75 material R&D activity from the SSIE program stand out in sharp contrast to the previous loosely defined and highly aggregated data shown in chapter 2. Tables 9, 10, and 11 show materials R&D activity by (1) number of sponsoring agencies, (2) for 1 miscellaneous and 11 specific material categories, and (3) by 7 phases of the materials cycle. The material developed for this report and contained in these tables corresponds to the type of data that the Committee on Materials task force is collecting and which should be available on a continuing basis into the future.

The data for fiscal year 1974 presented in table 9 shows graphically the multiplicity of research efforts in the materials area. In the metals category, for example, 52 subdivisions of 16 agencies were engaged in some 1,299 different research projects. In total, these accounted for about 15 percent of estimated dollar expenditures. The fuels category shows a similar pattern, with 65 sponsoring subdivisions accounting for 952 different projects and 38 percent of research expenditures. In total, these two categories accounted for almost 40 percent of research projects and 53 percent of total estimated expenditures. At the other extreme, only 83 bituminous materials projects were begun. They accounted for only half of 1 percent of estimated expenditures. Thus, substantial differences exist between materials categories.

Table 9

Federally-Funded Projects by Materials Category--SSIE

	Number of agencies	Number of sponsoring subdivisions	Number of projects	Percentage distribution of estimated dollars	Percentage of project reports submitted which show dollar estimates
Bituminous	8	10	83	.5	74
Plastics & rubber	12	36	594	5.0	55
Lubes & fluids	9	20	175	1.5	41
Composites	12	37	485	4.2	45
Coating	13	36	418	5.0	42
Ceramics & glass	14	35	449	5.8	55
Cement & clay	12	23	226	1.2	54
Textiles	13	22	275	2.8	15
Wood, pulp, & paper	12	23	266	1.9	9
Fuels	15	65	952	38.0	44
Metals	16	52	1299	15.1	52
Miscellaneous	15	44	442	19.0	37
	a 13	b 34	5664		45

Source: Special tabulation by SSIE.

a Average number of agencies per category.

b Average number of sponsoring subdivisions per category.

The SSIE data in tables 10 and 11 portrays Federal R&D effort phases of the materials cycle. An examination of these tables shows several significant points.

First, maximum participation by agencies appears to be in the "processing" and "use" areas, which account for about 85 percent of all Federally sponsored R&D projects. Program sponsoring subdivisions have more than twice as many materials R&D programs in these areas than in any other. Some 65 subdivisions sponsor R&D programs in the use area and 62 do so in the processing area. There is a long gap to the next most active area--"design". Twenty-nine subdivisions sponsor some 215 programs in this area.

Second, the three least active areas, in terms of number of projects, were the "disposal" (45 projects), "recycling" (106 projects), and "exploration" (169 projects) areas. These accounted for only 6 percent of all R&D projects.

Third, a comparison of the data in tables 10 and 11 shows that the emphasis of Federal materials R&D programs changed somewhat between 1974 and 1975.

In 1975 the exploration and extraction phases accounted for 10.4 percent of the projects and 12.0 percent of estimated dollars. In 1974 these figures were 7.9 percent and 15.0 percent, respectively. Recycling R&D accounted for 2.2 percent of the projects and 10.9 percent of the estimated expenditures in 1975 compared with 2.0 percent of the projects and 3.1 percent of the funds in 1974. Disposal R&D accounted for 1.5 percent of the projects and 1.8 percent of estimated expenditures in 1975, compared with 0.8 percent and 2.8 percent, respectively, in 1974.

PRESENT LIMITATIONS

The ability to formulate an intelligent and coherent approach toward the solution of significant materials problems require specific and detailed information. The SSIE data which was developed for us represent a first step in this direction. It is, however, only a first step and an expansion of the system is necessary if adequate data is to become available.

Table 10

Phases of the Materials Cycle Data
Federally-Funded Projects--FY 74

	Number of agencies	Number of sponsoring subdivisions	Number of projects	Percentage distribution of projects	Percentage distribution of estimated expenditures	Percentage of project reports submitted which show dollar estimates
Exploration	8	18	169	3.2	2.1	13
Extraction	10	27	249	4.7	12.9	53
Processing	15	62	1603	30.2	38.4	46
Design	15	29	215	4.0	3.0	35
Use	18	65	2926	55.1	37.7	47
Recycling	8	23	106	2.0	3.1	33
Disposal	7	16	45	.8	2.8	39
	a 12	b 34	c 5313	100.0	100.0	d 48

Source: Special tabulation of SSIE.

a Average number of agencies per phase.

b Average number of sponsoring subdivisions per phase.

c This total is greater than the actual total because of double counting of some projects that fit into more than one phase. This total includes more than $200 million of R&D expenditures in the fuel area. This product category is generally excluded from other cost estimates of materials R&D.

d Overall average.

Table 11

Phases of the Materials Cycle Data
Federally-Funded Projects--FY 1975 (note a)

	Number of agencies	Number of sponsoring subdivisions	Number of Projects	Percentage distribution of projects	Percentage distribution of estimated expenditures	Percentage of project reports submitted which show dollar estimates
Exploration	5	13	186	5.2	3.4	9
Extraction	7	20	187	5.2	8.6	17
Processing	15	43	1121	31.2	29.2	43
Design	10	23	139	3.9	7.0	38
Use	18	48	1825	50.8	39.1	45
Recycling	7	17	81	2.2	10.9	16
Disposal	6	12	52	1.5	1.8	23
	b 10	c 25	3591	100.0	100.0	d 40

Source: Special tabulation of SSIE

a Reported as of July 1, 1975.

b Average number of agencies per phase.

c Average number of sponsoring subdivisions per phase.

d Overall average

The present limitations are, for the most part, beyond the ability of the SSIE staff to remedy. Reference to some of these problems shows their range and relative significance. Most of them are related to the incompleteness of the data submitted to the SSIE.

1.--Some agencies do not report their research activities to the SSIE program. In the past, this seems to have been particularly true of the regulatory agencies. It appears that the Atomic Energy Commission was the only regulatory agency which reported to SSIE. Logic suggests that the Federal Power Commission, the Federal Communications Commission, the Interstate Commerce Commission, and the Federal Trade Commission might also be covered by the SSIE program.

2.--Some agencies limit the completeness of their submissions to SSIE. For example, they do not regularly submit information regarding the cost of in-house research programs. Data submitted for 1974 shows that only 18 percent of agency "in-house" research reporting forms contained dollar estimates. The overall average for all projects was 48 percent. The comparable overall figure for a partial submission of 1975 data shows this figure to be about 40 percent. Consequently, dollar estimates for Federally-sponsored R&D activity must be viewed as highly speculative.

3.--There appears to be either substantial underreporting of or a disregard for projects in social sciences. In 1974, social science studies constituted about 9 percent of all projects reported to SSIE. In the materials R&D area, that share dropped to about 1/2 of 1 percent. A number of authorities have pointed out that the least understood aspects of materials shortage are those related to economic, social, and political effects.

4.--Reporting is irregular. On the one hand, some agencies report monthly. The Department of Defense, for example, submits a monthly tape of its activity. But some agencies report quarterly or only annually. SSIE officials suggest that reporting for fiscal year 1974 is only 85-90 percent complete at this time. These irregularities add substantially to users' problems. The fault lies not with SSIE but with the reporting agencies.

5.--Although the charge given SSIE to act as a clearinghouse of R&D activity includes tabulating activity of private sources, few private firms actually report.

Moreover, the quality of their responses is poor. If the fiscal year 1974 data indicates the extent to which they participate in the materials field, the typical company response is only one or two per year. (See App. IV.)

6.--Data from the SSIE data bank is available at best for only 3 years--the current year and the 2 years just past. For example, 55 percent of fiscal year 1975 data have been received, while the estimate for fiscal year 1974 is 85-90 percent. Fiscal year 1973 data, which has been received in full, was transferred to microfilm as fiscal year 1976 data began to be received. Under the data storage method employed for noncurrent research, only current statistical data is economically accessible. Therefore, once the statistical data is stored on microfilm, it is, as a practical matter, lost for purposes of historical trend and other statistically-based types of examination.

SSIE DATA: AN ATTEMPTED CROSS-CHECK

Appendices II and III arrange the SSIE fiscal year 1974 data on the basis of materials R&D activity by supporting organization. The data shows the number of sponsored projects by agency, the number of projects for which funding data are available, and an SSIE estimate of the total materials R&D effort by agency.

To try to verify the data submitted to SSIE, SSIE data was cross-checked with agency data. Six agencies were chosen to compose a sample: the National Bureau of Standards, the Environmental Protection Agency, the Department of Agriculture, the Bureau of Mines, the Energy Research and Development Administration, and the Department of Defense.

RESULTS

The National Bureau of Standards data submitted to SSIE contained complete funding information; therefore, our interest revolved about the accuracy of the number of projects reported. The National Bureau maintains a central research-project file for each year. At the close of a year the file is given to SSIE to be inserted into its data bank. Our check indicated that the SSIE data matched that in National Bureau files in all relevant ways.

The Environmental Protection Agency, Department of Agriculture, and Bureau of Mines materials R&D data submitted to SSIE showed a fairly large number of projects. Examination showed that the forms submitted to SSIE correspond closely to data in agency files; however, cost data was almost non-existent. The Environmental Protection Agency attributed its lack of cost data to the decentralized nature of its research activity--its labs and research centers are located throughout the country. As a consequence the main office takes the data submitted to it and makes little or no effort to check the data's accuracy before transmiting it to SSIE.

The Department of Agriculture involves a second type of problem. Agriculture refuses to release project funding data. It reasons that listed costs per project are planning estimates (including arbitrary overhead allocations) rather than net research costs. It did agree that the SSIE estimate of Agriculture materials R&D expenditures was too low.

The situation with respect to the Bureau of Mines is similar to that of the Environmental Protection Agency in terms of project numbers, accuracy, and the problem associated with an extensive regional research organization. Research centers do not submit dollar data and the central coordinating office makes little effort to determine it.

The Department of Defense, the most active agency, apparently follows a standard reporting procedure in submitting unclassified materials R&D information to SSIE. Projects forms are sent in by research centers, labs, and contractors. Every 2 weeks a computer tape of unclassified R&D projects is put into the SSIE data bank. The number of projects reported to SSIE by Defense is apparently up-to-date and complete, but project forms often fail to include funding information. Moreover, Defense does not require that funding information be included on the project forms. Committee on Materials members feel that they are overcoming the general reluctance on the part of agencies to report dollar figures. The extent of this success will be seen when the "R&D Inventory Report" is available.

SSIE personnel believe that they are getting a fairly complete response from Federal agencies in terms of numbers of projects, and our sampling of agencies generally supports this belief. However, one exception was found in the former Atomic Energy Commission. One division of the Atomic Energy Commission published a listing of R&D projects for fiscal year 1974 which contained 227 materials R&D projects. The SSIE data, however, contained only 40 percent of these projects for that division. Thus, while the submission of descriptive project data appears to be fairly complete, there are still gaps in the reporting of projects by some agencies.

PROGRAM DEFICIENCIES

No data collection program exists which is free from criticism. The SSIE program is adversely affected by several deficiencies. The following statement in our 1972 report on the effectiveness of the SSIE program is still applicable to the present program.

> "Many government agencies are not using the Science Information Exchange to the fullest extent because, they claim, its data is not current or complete. At the same time, the abililty of the Exchange to provide current information is being hampered because the agencies are not providing the Exchange with the information it must have to perform the function of an information clearinghouse." 4/

These and other problems are attributable to the present "ground rules" which cover the operation of the system:

1. The system is voluntary; therefore, reporting is incomplete and erratic.

2. Budget constraints upon the SSIE program limit the usefulness of its noncurrent statistical data and make retrieving costs for such data unreasonably high.

3. Little data regarding private R&D activity is included. Thus, we can only appraise that part of national materials R&D activity associated with the Federal Government. Meanwhile, we assume that private sector R&D activity is highly important.

Estimates of private sector materials R&D activities are not available. The data which are available contain no breakdown between materials R&D, energy R&D, or any other R&D activities which might be of interest. Limited data covering private R&D activity on a broadly defined industry basis are available through the Bureau of the Census. They do not, however, contain any breakdown which deals with (1) area of research (materials, etc.) or (2) phases of the cycle. With so little known about private sector participation in materials R&D programs, attempts to achieve national R&D goals must be made with a large part of the relevant data missing.

CONCLUSIONS

The origin, growth, limitations, cost and value, and accuracy of the SSIE data have been treated in summary form in this chapter. It is clear that the SSIE program holds substantial promise for an adequate data collection and storage system. To achieve this promise requires that a number of changes be made.

This review of SSIE and other materials R&D data collection programs emphasizes the need for a comprehensive and detailed approach to both the R&D budget process and data bank. Data such as that contemplated by the Committee on Materials and developed for this report by SSIE provide the flexibility and adaptability which a useful data system should contain.

A coordinated, comprehensive materials R&D program need not and should not work against agency accomplishment of mission-oriented research. The needs are (1) to insure that maximum advantage is taken of the results of mission-oriented research and (2) to understand where additional effort should be expended so that overall materials R&D activity is responsive to both agency and national needs. This latter determination should be made, and national materials R&D priorities established, as one function of the needed materials policy institution discussed in Chapter I.

Through the formulation of balanced, integrated research strategies responsive to priority national goals (as discusssed in ch. 1), whether developed directly by the Committee on Materials or through use of lead agencies (as discussed in ch.2), these needs can be met. Data can also be assembled for the Office of Management and Budget to use during the budget formulation process so that a viable, policy-oriented materials R&D program can be presented to the Congress.

In reaching these conclusions, GAO has not only consulted with SSIE but also sought out the informed views of various officials knowledgeable in matters of Federal materials R&D.

CHAPTER 4

SUMMARY AND RECOMMENDATIONS

The basic purpose of this report has been to examine the management of Federal materials R&D efforts and to evaluate their effectiveness.

An evaluation of existing Federal R&D efforts must be conducted in relation to an appropriate frame of reference. Chapter 1 developed a such a framework through responses to six basic questions.

1. What should be the basic objectives of national materials policy?

The overall goal should be the protection of the domestic economy. This entails, in the short run, actions which will avoid or minimize the impact of severe shocks brought on by interruption in supply or rapid changes, particularly upward, in price. In the long run, goals are to assure continuity of supply and to minimize upward movements in materials prices.

2. Does a system exist which assigns priorities to actions needed to achieve basic objectives?

At the present time no such system exists. There is no established institution to assess alternatives and tradeoff considerations.

3. Has it become more difficult to attain the national materials goals in recent years?

It seems clear that it has become more difficult to achieve national materials goals. The reasons for this include: the diminishing supply of relatively inexpensive, high quality domestic resources with attendment increases in reliance on foreign sources; the potential constraining effects of necessary environmental regulations and increased costs (energy and other) of processing remaining lower grade domestic resources; and increasing volatility in international producer-consumer relations.

4. What alternatives are available to the Government to meet the nation's materials supply problems?

The basic governmental role has been one which seeks to compensate for deficiencies in the domestic market (price) system. Given the structure of private resource markets, an active governmental role is necessary. On the one hand, care must be taken to avoid undue restraints upon material production processes from environmental regulations, tax policy, depreciation policy, and antitrust prosecution. On the other hand, the governmental agencies are engaged in programs--resource conservation, stockpiling, promotion of international commodity arrangements, and R&D--which extend the life of known reserves or increase the supply of available materials.

5. How does R&D fit into an overall approach toward meeting national materials goals?

R&D is not the solution to all material shortage problems. It is most appropriately considered as the solution to medium- to long-range problems of material supply and efficient use.

6. What is an appropriate analytic framework for establishing materials R&D opportunities and priorities?

The development of an appropriate analytic framework begins with the identification of a specific material and the unique factors which affect its availability. This should be followed by the formulation of a comprehensive research program designed to include all relevant disciplines and relevant research approaches and which facilitate the establishment of priorities among them. Also, the development of such a framework should facilitate integrated decisionmaking during the budget formulation process.

In contrast to the integrated R&D materials management system above, chapter 2 described the actual path which efforts have followed since about 1960. These past efforts can be characterized as intermittent, incomplete, and poorly financed. There has been no apparent, serious interest by the Executive Office of the President in the conduct of Federal materials R&D activities. Symptomatic of this lack of serious commitment is the fact that we continue to deal with problems in this area through ad hoc interagency committees.

A necessary prerequisite to the management of materials R&D activities is a properly structured information system capable of producing relevant data. SSIE has an information collection and storage system in being which has some of the characteristics that a system adequate for R&D materials management would entail. The SSIE program could be made fully effective with a number of reasonable changes in agency reporting practices and in SSIE data processing and storage techniques. Chapter 3 and Appendix V present in detail the changes that should be made.

RECOMMENDATIONS

We recommend that the Congress consider statutory establishment of an institution to analyze materials issues and policy alternatives Government-wide. We further recommend that the now-functioning National Commission on Supplies and Shortages assign a high priority to fleshing out the details of the proposed institution and reporting them to the Congress.

At a minimum, the institution established should have as basic responsibilities (1) the analysis of policy options and trade-off considerations and (2) the provision of definitive guidance to operating agencies in planning for and executing materials policy. One component of the anticipated guidance would pertain specifically to perceived priority opportunities and problem areas in materials R&D.

The institution settled upon should seek to supplement and not to supplant existing agency systems. It should develop an overall governmental capability for materials policy monitoring, evaluating, forecasting, and planning through systematic improvements in the collection, standardization, comparability, coordination, and dissemination of economic and materials information. The institution should not be designed for basic data collection. Rather it should take data developed by operating agencies and use it for policy analysis.

The building of the needed institutional capability need not necessarily await further legislative action. It could perhaps be developed initially under the supervision of the National Commission on Supplies and Shortages, and begin there to acquire operational experience.

Where the institutional capability should reside permanently is an open question at this time. In our view, considering the many Federal agencies which deal with materials problems, the least desirable option would be to assign the responsibility to a single existing bureau or department. But if a Department of Energy and Natural Resources were established--an action we have suggested on numerous earlier occasions--this would have the effect of enhancing the Federal Government's ability to deal with its materials problems on a coordinated and cohesive basis.

Establishment of a Department of Energy and Natural Resources, alone, would not suffice however, Its creation would have to be coupled with establishment of a Cabinet-level Council on Materials. The Council would be chaired by the Secretary of DENR but would include representation from all agencies having a significant role in meeting national materials goals. Only through such a Council could adequate scope be assured for issue analysis and policy formulation. Without a DENR, and related Council, we believe the ony other adequate permanent option would be to establish the needed insitution within the Executive Office of the President, perhaps as a function of the Council of Economic Advisors.

We recommend that the National Commission on Supplies and Shortages work with the Executive Office of the President to establish an unclassified materials R&D information system with mandatory Federal reporting to SSIE.

Such a system is required for the effective management of the R&D component of a national materials program. We believe the information system should be an expansion of the existing SSIE program, with data input appropriately modified by the Committee on Materials fiscal year 1976 materials R&D inventory. SSIE should be charged, as it is for water resources research, with operating the program for the use of the Congress, all Executive departments, and other interested parties.

The system can be established under existing authorities. Should the Executive Branch not take advantage of these, the National Commission on Supplies and Shortages should recommend appropriate legislative action.

We recommend that SSIE collect data pertinent to private sector materials R&D for inclusion in its basic information system.

The concern is with the resolution of national materials problems; therefore, it is necessary to evaluate the allocation of total resources. Federal and private sector materials R&D efforts should complement one another. Knowledge of the Federal effort only will not assure the most productive allocation of Federal resources. SSIE should be charged with the responsibility of implementing this section of the program by seeking out the active coorperation of industry trade associations, individual firms, independent R&D contractors, and the university community.

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———David F. Hersey, Ph. D., *President*

October 22, 1975

Mr. Victor L. Lowe
Director
General Government Division
United States General Accounting Office
Washington, D. C. 20548

Dear Mr. Lowe:

In response to your letter of October 16, I am pleased to enclose my comments on the proposed report to Senators Tunney and Brock.

I have reviewed the draft along with other members of my staff and appreciate the opportunity which you have afforded me for review and comment.

Sincerely,

David F. Hersey
President

Enclosure

DFH/pm

GAO note: The enclosure contained general and technical comments on our draft report which have been incorporated into the final report.

———a nonprofit corporation of the Smithsonian Institution———

MATERIALS RESEARCH EXPENDITURES BY PERFORMING ORGANIZATION

	No. w/$	No. w/o $	Total no.	Total $ no. w/$	Average $	Est. $ for total $
Smithsonian Institution		4	4			
U.S. Air Force	1	128	129	$ 466,000	$466,000	$ 60,114,000
U.S. Army	19	525	544	1,861,627	97,980	53,301,120
U.S. Dept. of Agriculture	1	148	149	50,000	50,000	7,450,000
U.S. Dept. of Commerce	145	38	183	13,771,236	94,974	17,380,242
U.S. Dept. of Defense		1	1			
U.S. Dept. of Health, Ed., & Wel.		14	14			
U.S. Dept. of the Interior	193	499	692	53,437,315	276,877	191,598,884
U.S. Dept. of Transportation	17	10	27	1,540,000	90,588	2,445,876
U.S. District of Columbia Govt.	1	1	2	500	500	1,000
U.S. Energy Res. & Dev. Admin.	1	6	7	50,000	50,000	350,000
U.S. Environ. Protection Agency	1	40	41	42,000	42,000	1,722,000
U.S. Natl. Aero. & Space Adm.	1	97	98	500,000	500,000	49,000,000
U.S. Navy	15	323	338	2,241,000	149,400	50,497,200
U.S. Small Business Admin.	1		1	3,150	3,150	3,150
U.S. Tennessee Valley Auth.	15	13	28	1,706,300	113,753	3,185,084
U.S. Veterans Administration		66	66			
Total	411	1,913	2,324	$75,669,128	$184,109	$427,869,316

Source: SSIE data, "Summary of Materials R&D Expenditures by Performing Organization."

APPENDIX II

MATERIALS RESEARCH EXPENDITURES BY SOURCE OF FUNDS

	No. w/$	No. w/o $	Total no.	Total $ No. w/$	Average $	Est. $ for total $
Smithsonian Institution						
Astrophysical Observatory		1	1			
Museum of History & Technology		1	1			
Museum of Natural History		2	2			
Smithsonian Institution		4	4			
U.S. Atomic Energy Commission						
Applied Technology Division	7	1	8	$ 4,800,000	$685,714	$ 5,485,712
Biomedical & Env. Res. Div.	8	7	15	959,380	119,922	1,798,830
Controlled Thermo. Res. Div.	3		3	821,993	273,997	821,990
Office of Planning & Analysis	1		1	75,000	75,000	75,000
Other unknown Divisions	3	3	6	2,000,000	666,666	3,999,996
Physical Research Division	60	2	62	3,139,728	52,328	3,244,336
Reactor Research & Devel. Div.	27	4	31	16,691,000	618,185	19,163,735
Waste Management & Trans. Div.	5		5	2,198,000	439,600	2,198,000
U.S. Atomic Energy Commission	114	17	131	30,685,101	269,167	35,260,877
U.S. Consumer Prod. Safe. Comm.	4		4	679,000	169,750	679,000
U.S. Dept. of Agriculture						
Agricultural Research Service	1	147	148	50,000	50,000	7,400,000
Cooperative State Res. Service		184	184			
Economic Research Service		6	6			
Forest Service	1	61	62	8,000	8,000	496,000
Other unknown Service	2		2	72,000	36,000	72,000
Rural Electrification Admin.	1		1	120,000	120,000	120,000
U.S. Dept. of Agriculture	5	398	403	250,000	50,000	20,150,000

APPENDIX III

	No. w/$	No. w/o $	Total no.	Total $ no. w/$	Average $	Est. $ for total $
U.S. Dept. of Commerce						
Economic Development Admin.		1	1			
Maritime Admininstration		2	2			
National Bureau of Standards	105	12	117	$ 10,163,400	$ 96,794	$ 11,324,898
National Oceanic & Atm. Admin.	5	7	12	460,842	92,168	1,106,016
U.S. Dept. of Commerce	110	22	132	10,624,242	96,584	12,749,088
U.S. Dept. of Defense						
Air Force	247	139	386	11,807,072	47,801	18,451,186
Army	301	587	888	17,094,335	56,791	50,430,408
Defense Adv. Res. Proj. Agency	8	6	14	22,188,931	2,773,616	38,830,624
Defense Nuclear Agency		3	3			
Navy	304	355	659	13,946,444	45,876	30,232,284
U.S. Dept. of Defense	860	1,090	1,950	65,036,782	75,624	147,466,800
U.S. Dept. of Health Ed. & Wel.						
Public Health Service	112	38	150	8,648,612	77,219	11,582,850
Social & Rehabilitation Serv.	5		5	91,669	18,333	91,669
U.S. Dept. of Health, Ed., & Wel.	117	38	155	8,740,281	74,703	11,578,965
U.S. Dept. of Housing and Urb. Dev.	6	1	7	642,500	107,083	749,581
U.S. Dept. of Justice	4		4	820,000	205,000	820,000
U.S. Dept. of State						
Agency for Internat. Dev.		1	1			
Bureau of Intelligence & Res.		1	1			
U.S. Dept. of State		2	2			

APPENDIX III

	No. w/$	No. w/o $	Total no.	Total $ no. w/$	Average $	Est. $ for total
U.S. Dept. of the Interior						
Asst. Sect. Energy & Minerals	2	4	6	$ 138,667	$ 69,333	$ 415,998
Bureau of Mines	180	159	339	48,251,277	268,062	90,873,018
Bureau of Reclamation	26	2	28	294,000	11,307	316,596
Geological Survey	25	341	366	9,307,265	372,290	136,258,140
National Park Service	1	1	2	60,000	60,000	120,000
Office of Coal Research	28	34	62	21,852,604	780,450	48,387,900
Office of Saline Water	18	2	20	2,086,404	115,911	2,318,220
Office of Water Resources Res.	9	9	18	186,525	20,725	373,050
U.S. Dept. of the Interior	289	552	841	82,176,742	284,348	239,136,668
U.S. Dept. of the Treasury						
Bureau of Engraving & Printing	1		1	40,000	40,000	40,000
U.S. Dept. of the Treasury	1		1	40,000	40,000	40,000
U.S. Dept. of Transportation						
Coast Guard	5	4	9	334,831	66,966	602,694
Federal Aviation Admin.	2	4	6	293,400	146,700	880,200
Federal Highway Admin.	231	83	314	6,890,858	29,830	9,366,620
Federal Railroad Admin.	3	2	5	2,391,221	797,073	3,985,365
Natl. Hwy. Traffic Safety Adm.	4	8	12	534,713	135,928	1,631,136
Office of the Secretary	52	3	55	1,840,542	35,395	1,946,725
Urban Mass Transportation Adm.		2	2			
U.S. Dept. of Transportation	297	106	403	12,294,565	41,395	16,682,185
U.S. District of Columbia Govt.	1		1	60,000	60,000	60,000
U.S. Energy Res. & Dev. Admin.						
Biomedical & Env. Res. Div.	1		1	10,200	10,200	10,200
U.S. Energy Res. & Dev. Admin.	1		1	10,200	10,200	10,200

APPENDIX III

	No. w/$	No. w/o $	Total no.	Total $ no. w/$	Average $	Est. $ for total $
U.S. Environ. Protection Agy.						
Control Systems Lab. Division	3		3	$ 1,299,675	$ 433,225	$ 1,299,675
Office of Air Programs	1	20	21	1,700,000	1,700,000	35,700,000
Office of Planning & Manag.		1	1			
Office of Research & Dev.	5	172	177	614,114	122,822	21,739,494
Office of Solid Waste	1		1	1,924,500	1,924,500	1,924,500
Office of Water Programs		1	1			
Other Unknown Offices	6	10	16	803,017	133,836	2,141,376
U.S. Environ. Protection Agy.	16	204	220	6,341,306	396,331	87,192,820
U.S. Exec. Office of the Pres.						
Council on Environ. Quality		1	1			
U.S. Exec. Office of the Pres.		1	1			
U.S. Natl. Aero. & Space Adm.						
Aeronautics & Space Tech. Off.	2	84	86	350,000	175,000	15,050,000
Headquarters		1	1			
Manned Space Flight Office		9	9			
Organization & Management Off.	107		107	1,464,935	13,690	1,464,935
Other Unknown Office		3	3			
Space Sci. & Applications Off.		8	8			
Space Science Office		3	3			
U.S. Natl. Aero. & Space Adm.	109	108	217	1,814,935	16,650	3,613,050

APPENDIX III

	No. w/$	No. w/o $	Total no.	Total $ no. w/$	Average $	Est. $ for total $
U.S. Natl. Science Foundation						
Div. Adv. Energy Res. & Tech.	9		9	$ 1,405,291	$156,143	$ 1,405,291
Div. of Adv. Tech. Appl.	46	1	47	6,719,170	146,068	6,865,196
Div. of Biological & Med. Sci.	2		2	19,250	9,625	19,250
Div. of Engineering	132	4	136	3,750,356	28,411	3,863,896
Div. of Env. Systems & Resou.	9		9	1,393,600	154,844	1,393,600
Div. of Environmental Sci.	14		14	403,750	28,839	403,750
Div. of Higher Ed. in Sci.	4		4	60,286	15,071	60,286
Div. of Materials Research	227	3	230	17,508,700	77,130	17,739,900
Div. of Math. & Physical Sci.	27	1	28	683,950	25,331	709,268
Div. of Natl. & Internat. Prg.	27	1	28	841,502	31,166	872,648
Div. of Soc. Sys. & Hu. Resour.	1		1	18,600	18,600	18,600
Div. of Social Sciences	2		2	28,400	14,200	28,400
Expl. Res. & Prob. Assessment	2		2	157,200	78,600	157,200
Off. of Energy R&D Policy	4		4	318,850	79,712	318,850
Off. of Expt. R&D Incentives	1		1	50,000	50,000	50,000
Off. of Intergovt. Sci. & Res.	1		1	50,000	50,000	50,000
Off. of Natl. R&D Assessment	2		2	198,700	99,350	198,700
Off. of Syst. Integrat. Anal.	2		2	244,800	122,400	244,800
Other unknown units	6	14	20	1,190,166	198,361	3,967,220
Research Applications Direct.	9		9	880,100	97,788	880,100
U.S. Natl. Science Foundation	527	24	551	35,922,671	68,164	37,558,364
U.S. Ozarks Regional Comm.		1	1			
U.S. Postal Service	1		1			
U.S. Tennessee Valley Auth.	14	11	25	1,698,800	121,342	3,033,550
U.S. Veterans Administration		66	66			
Total	2,476	2,645	5,121	$257,837,125	$104,134	$533,270,214

Source: Federal Government section of SSIE data, "Summary of Materials R&D Expenditures by Supporting Organization."

APPENDIX III

SSIE DATA ON CORPORATION-SUPPORTED MATERIALS R&D PROJECTS

	No. w/$	No. w/o $	Total no.	Total $ no. w/$	Average $	Est. $ for total $
Air Products & Chemicals Inc.		4	4			
Aluminum Co. of America	1	9	10	$ 5,000	$ 5,000	$ 50, 00
Armstrong Cork Co.	1		1	8,000	8,000	8,000
Atlantic Richfield Co.		8	8			
Barber-Greene Co.		1	1			
Bechtel Inc.		4	4			
Bendix Corp.		1	1			
Bethlehem Steel Corp.		8	8			
Boeing Co.		2	2			
Brown & Root Inc.		1	1			
Buckley & Scott Co.		1	1			
Burlington Northern Rwy. Co.	1		1	12,000	12,000	12,000
Catalysts & Chemicals Inc.		1	1			
Caterpillar Tractor Co.		1	1			
Champion Spark Plug Co.		1	1			
Chicago Bridge & Iron Co.		1	1			
Chrysler Corp.		3	3			
Combustion Engineering Inc.		4	4			
Consolidated Coal Co.		4	4			
Continental Oil Co.		1	1			
Curtiss Wright Corp.		1	1			
Dravo Corp.		1	1			
E.I. Dupont DeNemours & Co.		1	1			
Eason Oil Co.		1	1			
Ethyl Corp.		1	1			
Exxon Corp.		21	21			
Ford Motor Co.		1	1			
Foster Wheeler Corp.		1	1			
General Atomic Co.		1	1			
General Electric Co.		3	3			

APPENDIX IV

	No. w/$	No. w/o $	Total no.	Total $ no. w/$	Average $	Est. $ for total $
General Motors Corp.		1	1	$	$	$
Gulf Oil Corp.		16	16			
Illinois Coal Gasification G.P.	1		1	6,000	6,000	6,000
International Business Machines		3	3			
International Harvester Co.		1	1			
Kennecott Copper Corp.		1	1			
Marathon Oil Co.	3	4	7	120,000	40,000	280,000
Mobil Oil Corp.		5	5			
National Steel Corp.		2	2			
North American Rockwell Corp.		1	1			
Occidental Petroleum Corp.		1	1			
Owens Corning Fiberglass Corp.	1		1	1,600	1,600	1,600
PPG Industries, Inc.		3	3			
Peabody Coal Co.	1	1	2	185,800	185,800	371,600
Penzoil Co.		1	1			
Phillips Petroleum Co.		5	5			
Proctor & Gamble Mfg.Co.		1	1			
Republic Steel Corp.	1		1	2,500,000	2,500,000	2,500,000
Rockwell International Corp.		5	5			
Shell Oil Co.		6	6			
Standard Oil of California		5	5			
Standard Oil of Indiana		30	30			
Sun Oil Co.		6	6			
Texaco, Inc.		9	9			
Texas Instruments, Inc.		2	2			
Union Carbide Corp.		2	2			
United Aircraft Corp.	1	4	5	5,925,000	5,925,000	29,625,000
Universal Oil Products Co.		6	6			
Utah International, Inc.	1		1	750,000	750,000	750,000
Welex, Inc.		1	1			
White Motor Corp.		1	1			
Total	12	180	192	$9,513,400	$ 792,780	$152,213,760

APPENDIX IV

SUGGESTED GAO FORMAT FOR FEDERAL AGENCIES TO USE IN PREPARING PROJECT DATA FOR SUBMISSION TO SSIE

1. Project title
2. Agency project number (Sponsoring, supporting, or other)
3. Level of funding year
4. Project initiation date
5. Project funding to date
6. Performing agency or contractor
7. Project summary, including:

   a) Project scope
   b) Type of research (basic, applied, development as defined by SSIE)
   c) Materials cycle phases (exploration, extraction, design, process, use, recycling, and disposal)
   d) Materials category(ies) (metals, fuels, etc.)

      1) Specific type (e.g., aluminum, steel, cooper, etc., in metals)
      2) Specific purpose (e.g., higher strength, better corrosion resistance, etc.)
      3) Specific mission orientation--short- or long-term benefits; (e.g., coal gasification, beneficiation--short-term, 5 years)

RETRIEVAL DEFINITIONS FOR MATERIALS CYCLE PHASES

The seven materials cycle phases were derived by computer retrieval on the basis of SSIE's existing indexes. Thus the definitions used for the original indexing of these projects predetermined the mode of listing projects for each phase, with the limitation that only those projects previously selected as dealing with some aspect of materials can be included. Following are the definitions and/or detailed identifiers for the principal indexes used in retrieving each materials cycle phase.

Exploration

The search for deposits of useful minerals, fossil fuels, or building materials. All techniques used for exploration are included.

Extraction

Mining--the process of extracting mineral deposits or building materials from the earth. Project indexing includes engineering aspects, types of mining operations, mining methods, and mine safety.

Beneficiation, extraction, and refining--this index covers those phsical and chemical processes which lead to obtaining a desired metal or other material from its ore in a sufficiently pure form for use.

Processing

Since processing is a very broad term when applied to the entire field of materials, a number of indexes are used--including those for casting, chemical processing, fabricating, machining, bonding, braxing, soldering, welding, thermal treatment, powder consolidation and densification, pelletizing, powder production, sintering, chemical engineering processes, and surface cleaning and finishing.

Design

The SSIE indexes dealing with design include architectural design, design codes and standards, environmental design, structural design, interior design, hydraulic design, design of instrumentation, transportation engineering design, materials design data, electromechanical design, design of waste water treatment facilities, chemical engineering plant design, and clothing and textile design.

Use and performance

The closest approach of SSIE indexes to this phase is to select fields of application, such as construction, medicine, fuel utilization,and desalination. In addition, corrosion and deterioration are treated as being applicable to use and performance.

Recycling

The recovery and processing of materials which would ordinarily be lost or wasted, in order that they can be put to practical use. New products form and uses for waste materials are included, as well as the reuse of materials for their original purposes.

Disposal

All aspects of waste materials disposal are included, such as incineration, landfill, ocean dumping, and processing for disposal.

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