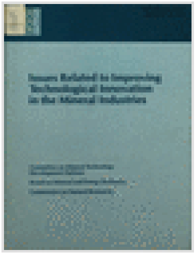

Issues Related to Improving Technological Innovation in the Mineral Industries (1981)

Pages
116

Size
8.5 x 10

ISBN
0309330823

Committee on Mineral Technology Development Options; Board on Mineral and Energy Resources; Commission on Natural Resources; National Research Council

Issues Related to Improving Technological Innovation in the Mineral Industries

A Report Prepared by the
Committee on Mineral Technology Development Options
Board on Mineral and Energy Resources
Commission on Natural Resources
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C. 1981

This study was supported by the U.S. Bureau of Mines.

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ACKNOWLEDGMENTS

The Committee acknowledges the contributions made by officers of private organizations and federal agencies who generously answered questions and discussed the matter of incentives and disincentives to technological innovation.

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PREFACE

The problems of technological innovation in the mineral industries stem from a wide variety of factors, many of which are common to industry in general. Significantly, however, there are unique or unusual characteristics of the mineral industries that bear heavily on a company's outlook on innovation and its ability to undertake new and risky technology enterprises.

The problems of the mineral industries, discussed at length and brought into focus by the Paley Commission in its 1952 report "Resources for Freedom", are clearly ones of long standing that have spanned several government administrations. The National Academy of Sciences, in its 1969 publication Mineral Science and Technology: Needs, Challenges, and Opportunities, further reported on the state of mineral science and technology. In the Academy's 1978 report, Technological Innovation and Forces for Change in the Mineral Industry, the barriers to technological innovation were examined. The present report, covering the period through November 1980, is an additional contribution to an understanding of the problems bearing on technological innovation in the mineral industries and the need to encourage and stimulate new technology for domestic mineral production.

The essential value of this report is 1) the contemporary description of the issues, 2) a reminder that many of these issues are of long duration, and 3) the recognition that industry, universities and government all have important roles to perform in resolving these issues. Furthermore, it is valuable to recognize that the issues identified in this report as well as some of the recommendations for their resolution are both important and timely. Indeed, some are already receiving attention. The former administration initiated an examination of federal activities in nonfuel mineral policy and the present administration is taking additional important steps in this direction. Among these are a review of the stockpiling of strategic minerals, studies of regulatory reform, and an examination of financial incentives for industrial modernization. This report, therefore, serves a valuable purpose of directing attention to the primary issues related to technological innovation in the nonfuel minerals industry and provides a rationale for industry, university and government interaction in their resolution.

Charles J. Mankin, Chairman
Board on Mineral and Energy Resources

OVERVIEW

> Technological innovation is the driving force behind economic growth in the United States. In this context "innovation" means the process by which a new idea is successfully translated into economic impact within our society by providing better products and simultaneously creating new jobs in the manufacturing and application of those products. Thus, an idea or invention is a necessary but not sufficient prerequisite for innovation. Only after an invention is put into sufficient use to have an economic effect is it to be termed an innovation.
>
> --Robert A. Charpie (1967)

The United States is becoming increasingly dependent on foreign countries for mineral raw materials essential to its industrial enterprise. Recently this dependency has become not just a mineral resource dependency but also a mineral processing dependency. The details of this dependency have been extensively examined in numerous studies and analyses by the National Research Council and others. The most recent of these is the report of the Subcommittee on Mines and Mining of the Committee on Interior and Insular Affairs of the U.S. House of Representatives (1980a) titled "U.S. Minerals Vulnerability: National Policy Implications." The highlights of this report are given in Appendix A. A major reason for the increasing dependence on foreign imports is that the domestic mineral industries are no longer as advanced in mineral-processing technology as many of their foreign competitors and lacking technological solutions to present problems, these industries are faltering. If it is considered in the national interest to maintain a strong and healthy domestic mineral industry, then special attention will have to be given to improving the development and adoption of new mineral technology.

The problem of technology deficiency in the mineral industries has been addressed in both the Mining and Minerals Policy Act of 1970 and the National Minerals and Materials Policy Research and Development Act of 1980. However, neither of these acts has resulted in definitive action on the part of either government or industry to remedy this deficiency. Numerous studies have pointed to a general decline in industrial innovation in the United States in recent years, and the Executive Office of the President during 1980 completed a domestic policy review on innovation that further elaborated on this decline. Several other studies have specifically addressed this decline within the mineral industries.

Many factors have contributed to our failure to improve our mineral technology. These range from unusual characteristics of the mineral industries to policies and actions of the government that discourage innovation. The National Research Council, through its Committee on Mineral Technology Development Options, has continued to study the problem of declining technology and has developed recommendations on actions that might be taken by the federal government, the companies comprising the mineral industries, universities, and professional societies to enhance cooperation and to stimulate technological innovation in the mineral industries.

The driving force behind technological innovation is the expectation of a satisfactory return on invested capital. Thus, if there are factors, real or perceived, that are likely to increase cost, lengthen the time to commercialization, increase risk, or otherwise reduce the return on investment, innovation will be discouraged. No innovation will take place, regardless of the amount of R&D performed or the salience of its results, if anticipations of return on investment are negative or low.

Therefore, the Committee has concluded that for innovation to occur in the mineral industries two conditions must exist: (1) adequate business incentives must exist to encourage both the initiation of the innovation process and the steps leading to commercialization--i.e., the business and political atmosphere must be favorable--and (2) an institutional structure must focus the necessary science and engineering talents on the research, development, and demonstration (RD&D) phases of the process so that opportunities for investment can be created.

In the last quarter century, the changing set of incentives and disincentives for innovation by the mineral industries has discouraged innovation and brought on a decline in the vitality of the industries. This has resulted in increased import dependence by the United States. Neither the business incentives nor institutional structures were sufficiently strong during that period to encourage technological innovation on a broad front. Without new reasoned actions by both government and the mineral industries, conditions will continue to discourage technological innovation and limit concomitant benefits to the country.

If adequate business incentives are to materialize, the federal government will have to provide a favorable atmosphere for technological innovation by adjusting policies and regulations that currently discourage innovation. The federal government should also assist in the innovation process through the support of RD&D in areas involving innovation for social benefit, the use of domestic resources, and in those cases where the risk and cost of demonstration

1. INTRODUCTION

There are a number of indications that the United States may be witnessing the early stages of a "raw materials crisis" that will have many of the attributes of the "energy crisis." Because of the great diversity of nonfuel minerals and their sources of supply, it has generally been supposed that actions like OPEC's cannot take place with most nonfuel minerals. On a number of occasions in the last several years, however, supplies of vital mineral commodities such as bauxite, chromium, cobalt, and tantalum have been interrupted or their prices increased at an abnormal rate. As with petroleum, the United States is becoming increasingly dependent on politically sensitive countries--for example, Gabon, Guinea, South Africa, Jamaica, Surinam, Zaire, Zambia, Zimbabwe, and the USSR--for many of the critical metallic and nonmetallic mineral commodities required to sustain the U.S. economy and to insure its security. The United States has both a mineral resource dependency and a mineral processing dependency inasmuch as increasing quantities of processed mineral-derived products are being imported in the form of metals and alloys. While some would argue that this is healthy, history has shown that even friendly governments can control prices and production in a manner that may be disadvantageous to the United States, such as happened with Canadian and Mexican controls on natural gas. In addition, there are national defense implications to dependence on imports for many of our mineral commodities.

What may be a "raw materials crisis" seems to be emerging at a time when the application of science and technology to problems of the mineral industries is at a low ebb. Dee (1980) summarizes the state of affairs of industry in general in these words:

> Of the many economic problems facing the United States today, one of the most frustrating has been the nation's growing inability to increase productivity through technological innovation. This failure has reduced our ability to compete with other nations in the world marketplace and has contributed significantly to inflation as productivity has lagged behind wages.

THE PROBLEM OF MINERAL SUPPLY

Data of the Bureau of Mines (1979) show that the United States now imports nearly half of the dollar value of minerals and metals needed to keep the wheels of America turning--e.g., manganese and chromium for steel, tantalum for electronics, cobalt and nickel for jet engines, and the platinum-group metals for catalysts in automobile muffler systems. Import dependency for several metals (columbium, strontium, titanium, manganese, tantalum, aluminum [as bauxite and alumina], cobalt, chromium, and the platinum group metals) is in excess of 90 percent of consumption. For example, 92 percent of our chromium is imported; of this, 35 percent comes from South Africa, 18 percent from the USSR. The United States is 97 percent dependent on imports for its cobalt supply, 42 percent of cobalt imports coming from Zaire and another 7 percent from Zambia. Some of this import dependency will of necessity continue simply because domestic sources do not exist for many mineral commodities. However, for certain minerals, such as lead and zinc, the potential for increased domestic production, and a lessening of dependence on foreign sources, is very real.

The National Commission on Materials Policy (1973), in its report <u>Material Needs and the Environment Today and Tomorrow</u>, projected that U.S. mineral dependency in the year 2000 will be over $60 billion per year. (It will, in fact, be nearer $100 billion in 1980 dollars.) Spot shortages of critical mineral commodities--cobalt, molybdenum, tantalum, titanium--have already occurred, and until the 1980 recession, prices for most mineral raw materials as well as for many other raw materials were rapidly rising, cobalt and platinum being extreme examples. The raw material shortages of 1973-1974 following the high worldwide demand in 1972 appears now to have been a forewarning of events to come.

The National Commission on Supplies and Shortages (NCSS 1976) attributed the 1973-1974 commodity shortages to three factors: a worldwide surge in demand, insufficient production capacity, and a "shortage mentality." Most important, the commission determined that a high proportion of the spot shortages were due not to resource exhaustion but either directly or indirectly to the actions of governments.

President Truman perceived the possibility of an import dependency problem in 1950, and he commissioned a panel of citizens under the chairmanship of William S. Paley to investigate the status of the United States with regard to raw materials and energy. In <u>Resources for Freedom</u>, the President's Materials Policy Commission (1952) reported that, although the balance of trade in minerals (excluding fuel minerals) was then positive, conditions were developing that, if not checked, would eventually lead to serious dependency on foreign nations for vital energy and raw material goods. The report recommended that the federal government establish programs for ensuring a stable flow of materials from both domestic and foreign sources at the lowest cost consistent with national security and the welfare of friendly nations. Unfortunately, few if any of the Paley Commission recommendations were implemented.

In recent years, the United States has had annual deficits of $2 billion to $8 billion in mineral trade. The imbalance for 1979 was down to $2 billion, owing to a large export of gold ($5 billion) and plastics ($2.9 billion)* as reported by the U.S. Department of Commerce and summarized in Table 1.1. Because of growing problems in domestic mineral supply brought about by diminishing ore grade, high labor costs, high energy costs, and environmental regulations, in 1977 the President ordered an interagency study, the Domestic Policy Review of Nonfuel Minerals. While a final report on this study has not been issued, the working papers indicate, among other things, that the problems of obtaining mineral supplies from domestic sources are becoming increasingly complex, and a variety of steps must be taken, including the development and installation of new technology, if our domestic supplies of mineral materials are to be improved. The most recent analysis of the problems of U.S. mineral supply was made by the House Subcommittee on Mines and Mining and was released in November 1980 (U.S. House of Representatives 1980a). With the exception of the limited programs of the Bureau of Mines, there has been no concerted effort on the part of the federal government to improve the technological status of the American mineral industries.

Out of concern for predicted material problems in general, and concern for materials R&D in particular, the Federal Council for Science and Technology established the Interagency Committee on Materials (COMAT) in 1975 to

> identify key points of emphasis for federal materials R&D within the context of the total materials system (or cycle) in the economy--from the origin of resources, both renewable and nonrenewable, through translation into materials for use to their disposal. [COMAT 1976, p. 1]

In 1976 COMAT conducted an inventory of federal expenditures in "materials life cycle R&D," based on the definition of materials as

> such substances as minerals, metals, ceramics, semiconductors, dielectrics, glasses, polymers, and natural substances like wood, fibers, leather, and other non-food agricultural and animal products. It excludes foods, drugs, and fuels. [COMAT 1976, p. 1]

Table 1.2 shows the distribution of funds for R&D on materials as related to function (stages in the materials cycle) for FY 1976, as inventoried by COMAT with the assistance of Battelle-Columbus Laboratories.

As part of the President's Domestic Policy Review of Nonfuel Minerals, the National Science Foundation (NSF) analyzed the FY 1976 COMAT data for the component that pertained to nonfuel minerals. Table

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*Imports and exports of plastics are included as part of the Bureau of Mines reporting of foreign trade in raw and processed nonfuel minerals. Plastics, however, are a processed form of fuel minerals.

TABLE 1.1 U.S. Imports and Exports of Raw and Processed Nonfuel Minerals (in $Billions)

Commodity	1978			1979			Change
	Import	Export	Difference	Import	Export	Difference	1979-78
Iron and steel	6.5	2.1	(4.4)	7.8	2.6	(5.2)	(0.8)
Iron and steel scrap	-	0.7	0.7	-	1.2	1.2	0.5
Iron ore	0.9	-	(0.9)	0.9	-	(0.9)	-
Manganese	0.2	-	(0.2)	0.3	-	(0.3)	(0.1)
Gold	0.9	1.1	0.2	1.5	5.0	3.5	3.3
Chromium	0.2	-	(0.2)	0.2	-	(0.2)	-
Nickel	0.9	0.2	(0.7)	0.9	0.3	(0.6)	0.1
Silver and platinum	0.8	0.2	(0.6)	1.7	0.7	(1.0)	(0.4)
Cement	0.2	-	(0.2)	0.3	-	(0.3)	(0.1)
Molybdenum	-	0.4	0.4	-	0.8	0.8	0.4
Tin	0.6	-	(0.6)	0.8	-	(0.8)	(0.2)
Aluminum, alumina, bauxite	2.2	0.9	(1.3)	2.1	1.4	(0.7)	0.6
Titanium	0.2	-	(0.2)	0.2	-	(0.2)	-
Clays	-	0.2	0.2	-	0.3	0.3	0.1
Copper	0.9	0.6	(0.3)	0.9	0.8	(0.1)	0.3
Cobalt	0.2	-	(0.2)	0.5	-	(0.5)	(0.3)
Gem stones	2.3	0.8	(1.5)	2.2	1.0	(1.2)	0.3
Zinc	0.5	-	(0.5)	0.5	-	(0.5)	-
Phosphates	-	0.7	0.7	-	1.0	1.0	0.3
Nitrogen	0.5	0.3	(0.2)	0.4	0.4	0.0	0.2
Potash	0.4	-	(0.4)	0.5	-	(0.5)	(0.1)
Asbestos	0.2	-	(0.2)	0.2	-	(0.2)	-
Plastics	0.4	1.9	1.5	0.7	2.9	2.2	0.7
Other chemicals	0.2	0.6	0.4	0.2	0.8	0.6	0.4
All others	1.8	2.3	0.5	2.2	3.8	1.6	1.1
Total	21.0	13.0	(8.0)	25.0	23.0	(2.0)	6.0

SOURCE: Data from U.S. Bureau of Mines (1979).

TABLE 1.2 Distribution of FY 1976 Materials R&D Funds Related to Function (Stage in Materials Cycle) by Sponsoring Agency ($1,000)

Sponsoring Agency	Exploration for Resources	Extraction of Raw Materials	Processing of Raw Materials	Manufacture and Fabrication	Application and Utilization	Evaluation of Properties	Development of Materials	Waste Management	Unspecified	Total
Department of Commerce	–	–	72	708	3812	7194	1979	151	7164	21080
Department of Defense	–	–	184	2776	29390	25410	57373	60	16869	131881
Department of Interior	38308	80909	16100	375	2584	900	846	14105	11225	165350
Department of State	–	–	–	–	415	95	–	–	30	540
Department of Transportation	505	–	–	–	655	2370	2304	319	–	6153
Environmental Protection Agency	–	2879	4116	5187	2017	62394	–	21332	1474	99399
Energy Research and Development Administration	14000	152	30420	3240	124658	69089	7075	45485	38778	332897
General Services Administration	–	–	–	–	42	–	–	–	90	132
Department of Health, Education and Welfare	–	80	130	198	1179	13610	1039	96	293	16625
Department of Housing and Urban Development	–	–	–	–	2384	3850	325	100	30	6689
NASA	2324	–	–	–	26	11117	37639	–	427	51533
Nuclear Regulatory Commission	–	–	–	–	3501	2817	–	710	–	7028
National Science Foundation	4800	–	600	690	8000	19306	2680	6100	26526	68700
Smithsonian Institution	–	–	–	–	–	–	–	–	1000	1000
Tennessee Valley Authority	–	–	–	–	220	211	7266	1095	434	9226
Department of Agriculture	11	5064	8875	3070	8576	601	4208	4321	3528	38254
Department of Labor	–	–	–	–	63	–	–	–	4000	4063
Department of the Treasury	–	–	–	–	81	525	45	–	139	790
Totals	59,948	89,083	60,497	16,244	187,583	219,488	122,778	93,873	111,825	961,320
Percent[a]	7.0	10.5	7.1	1.9	22.1	25.8	14.5	11.1	–	100.0

(a) Excluding "Unspecified"

SOURCE: Battelle-Columbus Laboratories (1979).

1.3 shows the distribution of expenditures for nonfuel minerals/materials R&D by agency. Estimates made by Battelle-Columbus Laboratories (1979) for NSF on expenditures for minerals and materials R&D in the United States in the period 1976-1977 by sector are shown in Table 1.4.

These estimates of R&D expenditures are cause for concern. First, the expenditures for R&D in mineral supply (shown in Table 1.4 as exploration, mining, and minerals processing) are a minor portion of both total federal and total private expenditures for nonfuel minerals R&D. Note that in Table 1.4, federally funded R&D in exploration, mining, minerals processing, and primary material processing amounts to 8 percent, and industrially funded R&D amounts to 10.1 percent. Most of the federal R&D budget is consumed by expenditures for application and utilization, evaluation of properties, and development of materials--metals, alloys, and ceramics derived from nonfuel minerals. Second, the federal government spends much more on R&D in supply problems of fuel minerals and renewable resources than of nonfuel minerals. Third, although the estimated R&D expenditures of the private sector in such materials research is nearly double that of the federal sector, it too focuses, in the main, on materials-use problems rather than on materials-supply problems. Nevertheless, private sector expenditures on mineral supply problems exceeded federal expenditures by three to one. But even this apparently generous support is, in fact, relatively small compared with support in other industries in the United States (see Table 1.5).

THIS STUDY

The National Research Council (1978b), in its report Technological Innovation and Forces for Change in the Mineral Industry, called attention to forces already shaping needs for more advanced technology in the mineral industries. A subsequent report prepared for the National Science Foundation by Battelle-Columbus Laboratories (1979), under the Domestic Policy Review of Nonfuel Minerals, identified opportunities for minerals R&D, discussed recent federal funding patterns in nonfuel minerals R&D, and identified barriers that might retard this country's ability to conduct R&D and to use the resulting scientific and technological advances.

Since then, studies by the U.S. General Accounting Office (1979) and by the interagency Domestic Policy Review of Nonfuel Minerals (U.S. Department of the Interior 1979) have confirmed the previous concerns of the National Research Council (NRC 1978b) and have documented a noticeable decline in the position of the United States relative to its mineral raw-material needs. The conclusion of the interim report of the Domestic Policy Review of Nonfuel Minerals was that "there is some indication to suggest that the United States--that is, industry and government together--may not be investing aggressively in R&D at the front end of the minerals cycle. . . . The balance of minerals-related R&D may be too heavily weighted toward near-term, rapid payoff activities and insignificantly concentrated on longer-term work."

TABLE 1.3 Distribution of FY 1976 Nonfuel-Minerals/Materials R&D Efforts by Federal Agency Providing the Funding

Funding agency	$ Million	Percent
Energy Research and Development Administration	242	36.5
Department of Defense	132	19.8
Department of Interior	63	9.5
National Science Foundation	69	10.4
National Aeronautics and Space Administration	49	7.4
Environmental Protection Agency	36	5.4
Department of Commerce	21	3.2
Department of Health, Education and Welfare	14	2.1
Tennessee Valley Authority	9	1.4
Nuclear Regulatory Commission	7	1.1
Department of Housing and Urban Development	7	1.1
Department of Transportation	6	0.9
Department of Labor	4	0.6
Department of Agriculture	4	0.6
Smithsonian Institution	*	*
Department of Treasury	*	*
Department of State	*	*
General Services Administration	*	*
Total	663	100.0

*Less than $1 million.

SOURCE: Battelle-Columbus Laboratories (1979).

TABLE 1.4 Summary of Estimated Funding of Nonfuel-Minerals/Materials R&D in the United States, 1976-77

Part of the cycle	Federal funding: Millions of dollars annually	Federal funding: Percent	Industrial funding: Millions of dollars annually	Industrial funding: Percent
Exploration	19	3	2	0.1
Mining / Minerals processing	14	2	54	3
Primary material processing	17	3	116	7
Utilization of materials devoted explicitly to alleviating supply problems	5	<1	*	*
All other utilization	490	72	1564	88
Recycling	9	1	34	2
Unspecified	190	16	-	
Total	663		1770	

*No data are available. There is probably very little devoted to the purpose of conserving materials.

SOURCE: Battelle-Columbus Laboratories (1979).

TABLE 1.5 Expenditure for R&D in U.S. Industry, 1979

Industry	R&D expenditure Percent of sales	$ per employee
Aerospace	4.2	2412
Appliances	1.5	700
Automotive, vehicles	3.2	2628
Automotive, parts	1.5	780
Building materials	1.1	811
Chemicals	2.3	2152
Conglomerates	1.6	980
Containers	0.8	574
Drugs	4.8	2953
Electrical	2.8	1461
Electronics	2.5	1247
Food & beverages	0.5	420
Fuel, petroleum	0.4	1590
Information processing, hardware	6.1	3265
Information processing, office equipment	4.2	2367
Instruments	3.9	1734
Leisure-time products	4.2	2556
Machinery, farm, construction	2.7	2037
Machinery, tools, industry, mining	1.6	923
Metals & mining	0.5	878
Miscellaneous manufacturing	1.7	1032
Oil service & supply	1.7	940
Paper	0.8	651
Personal & home-care products	1.7	1552
Semiconductors	5.7	1922
Steel	0.6	423
Telecommunications	1.0	499
Textiles & apparel	0.6	241
Tires & rubber	1.7	990
Tobacco	0.3	312
Industry composite	1.9	1553

SOURCE: Data from Business Week (1980).

With the foregoing in mind, the Board on Mineral and Energy Resources of the National Research Council established the Committee on Mineral Technology Development Options to study and make recommendations on how the United States might better use the R&D resources and skills that currently exist and those that might be created to improve the rate of development and application of new technologies to help ensure domestic supplies of minerals. This volume reports the Committee's findings.

The Committee was composed of nine members, with backgrounds in mining, metallurgical and chemical engineering, chemistry, and economics; it included a diverse group of individuals ranging from academicians familar with problems of the mineral industries to former government employees involved with mineral resource affairs and present employees of the mineral industries. All have considerable knowledge of research, development, and demonstration (RD&D) programs in industry, government, and universities. The Committee began its study by tentatively identifying the main elements of the problem and examining pertinent literature. As part of its background study, members interviewed a representative cross-section of executives, mostly in the mineral industries, to obtain current views on the problems of innovation (see Acknowledgments). In addition, the Committee drew upon its own expertise for academic and governmental perceptions of the incentives and disincentives to technological innovation in the mineral industries. In assembling its ideas, it became clear to the Committee that there are two essential requirements of technological innovation: (1) people and the necessary means to carry out each stage of the innovation process, and (2) an appropriate climate for undertaking the entire process. Industry representatives particularly cited the need for large-scale demonstration projects before major investment decisions can be made as being characteristic of these industries.

This study examines the problems of declining innovation in mineral supply technology in the United States and looks at ways in which technological innovation can be stimulated through actions of the federal government, the mineral industries, universities, and professional societies. It discusses federal government programs and policies pertaining to industrial innovation and examines approaches to technological innovation both in the public and private sectors. The report concludes with an analysis of the Committee's findings and a presentation of recommendations drawn from these findings.* Appendix C addresses the relationships of government, industry, and technological innovation in a number of foreign countries.

For the purpose of this report the Committee considers "minerals" to be the solid minerals and excludes petroleum, natural gas, helium,

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*Since the completion of the Committee's studies the Congress passed and the President signed into law the National Minerals and Materials Policy Research and Development Act of 1980 as a final step in reconciling the deficiency in minerals and materials technology in the United States.

ana water. Thus, the "mineral industries" upon which this report focuses include those which produce metallic, nonmetallic, and solid-fuel minerals (coal and uranium) and mineral-derived products.

2. THE PROBLEM OF DECLINING INNOVATION IN MINERAL-SUPPLY TECHNOLOGY

Many forces have brought about a decline in the financial vitality of U.S.-based mineral-producing companies. Interested observers may be aware of some of the causes--changing environmental protection requirements, the increasing complexity of obtaining permits, and escalating costs of energy--but the debilitating effects of these and other forces on the financial condition of mineral industries in the United States are not widely appreciated. This loss in financial vitality, together with other factors, has resulted in a decline in mineral supply technology in the United States.

The U.S. General Accounting Office (1979) reported a decline in the return on invested capital for the mineral industries from nearly 17 percent in 1966 to 4 percent in 1977 (compared with the average of 15 percent for all U.S. manufacturing) and a rapid increase in the relationship of debt to total equity, from around 9 percent in 1966 to nearly 54 percent in 1977. These two trends severely limit most mineral companies' ability to modernize existing mines and processing plants and to build new ones. The decline in the return on invested capital limits the availability of internally generated funds, and the increase in debt reduces the firm's ability to attract external capital (see Table 2.1).

The difficulty of generating capital comes at the same time that the government is mandating special expenditures to meet regulatory standards. As a result, the mineral industries, according to some company executives, have deferred modernization and are operating with some relatively inefficient facilities. Furthermore, the inflation rate for plant and equipment in the mineral industries has been nearly twice the average national inflation rate, and in the last two or three years, the cost of major operating supplies, including energy, has increased at an annual rate of about 45 percent. Funds have therefore been diverted from capital expenses to operating expenses in order to maintain current operations. Costs of modernization have thus increased more rapidly than inflation; profitability is at a low ebb; and as a consequence, the index of plant and equipment expenditures for these industries has been considerably below the GNP index (Bureau of Mines 1979). The mineral industries are in a weakened financial

TABLE 2.1 U.S.-Based Mineral Industry Financial Trends

Year	Average percent return on invested capital*	Average percent of total capital in debt and preferred stock
1966	16.6	9.4
1967	12.5	9.7
1968	14.2	12.4
1969	18.5	17.9
1970	18.0	22.9
1971	10.6	30.2
1972	10.9	34.4
1973	14.8	38.1
1974	16.9	32.0
1975	8.9	40.5
1976	7.3	48.1
1977	3.9	53.8

*Return on investment computed after taxes; invested capital is equity and long-term debt with no credit for deferred taxes.

SOURCE: U.S. General Accounting Office (1979).

position, and available evidence portends no improvement unless major steps are taken to address the problem.

The consequences of lagging technological innovation and the weakening of the mineral-based industries in the United States are only beginning to be felt. Perhaps the most publicized effect has been the high unemployment rates in such traditional steel-making centers as Youngstown, Ohio, resulting from the weakened condition of the steel industry. A similar weakening of the nonferrous metals industry has affected jobs in Butte, Montana, and other smaller communities throughout the country. While macroeconomists argue that incentives should not be provided to discourage the movement of labor and other resources toward the more efficient industries where the United States enjoys a competitive advantage in international trade, it is also recognized that in the short run the adverse effects of imports on employment can be quite severe, particularly for certain regions within the country. More important than local employment effects is the loss of capacity to exploit our domestic resources.

Historically, the United States has been dependent on imports for all or much of its supply of certain minerals (e.g., tungsten, tin, cobalt, and chromium) and may well remain so. But we now import many mineral commodities for which we were once a major producer, even an exporter, and for which there are domestic sources to be investigated and possibly developed. In some cases, such as lead, zinc, and fluorspar, U.S. supplies have simply lost part or all of the market to foreign competitors because domestic operations could not remain competitive in the face of lagging technological innovation.

Some economists argue that reliance on foreign trade is perfectly acceptable insofar as it leads to the lowest-cost supplies of raw materials. Others, however, argue that the United States should not place its economy and its national security in a vulnerable position for admittedly small reductions in raw material costs. National security considerations are discussed in detail by Hanks (1980), Miller et al. (1980), and the U.S. House of Representatives Committee on Interior and Insular Affairs, Subcommittee on Mines and Mining (1980b). Since the 1973-74 raw-materials shortages, the destabilizing influences of new shortages such as cobalt and molybdenum have been apparent. Recent actions by a relatively few people in Iran have influenced our petroleum supply, and events in Zaire and Zambia, which provide most of the world's cobalt (including half of that used in the United States) have created market uncertainty and elevated prices for this important commodity. Because of the growing political unrest in foreign countries, it would appear to be increasingly desirable for the United States to improve its mineral technology, so that those mineral materials for which we do have domestic resources can be mined in competition with foreign production.

Mineral resource estimates by the Geological Survey and ore reserve data from the Bureau of Mines released in their extensive series of publications and collected in their respective data systems (USGS/CRIB and USBM/MAS) indicate that the United States has substantial resources of many important minerals, despite the depletion of readily accessible and high-grade deposits. See for example, USGS Professional Paper 820

(USGS 1973). However, inasmuch as it is technology and the ability to extract and process mineral resources economically which differentiates a "mineral deposit" from an "ore deposit," as ore grade declines technology must be capable of providing mineral commodities in a manner which is competitive with alternative sources of supply if the United States is to provide for its needs. While the United States will never be completely self-sufficient in all mineral commodities it could recover much of its international advantage by using technologically advanced mining and processing systems.

Present plants and equipment for the mineral industries in the United States and throughout the world were built largely in an era of cheap energy, easily accessible deposits and high-grade ore, and few environmental, safety, and health controls. Today, there are numerous ideas for radically new processes that appear to be consistent with emerging energy, environmental, safety, and health requirements. Companies in the mineral industries, however, have been generally unwilling--in view of their perceptions of the future economic and political environment--to consider such long-term possibilities.

Technological innovation has been defined by the National Science Foundation (1976) as "all aspects of the process of innovation from conception or generation of an idea to its widespread utilization by society, including activities involved in the creation, research, and development and diffusion of new and improved products, processes and services for private and public use."

A common perception exists that the conduct of basic research of sufficient quantity and quality leads inevitably to technological innovation and economic growth (Figure 2.1). A more realistic view reflecting the NSF definition, recognizes that technological innovation is a complex process subject to many influences (Figure 2.2). R&D influences technological innovation and is an indispensable part of the innovation process, but it does not determine innovation. The driving force of the process is the expectation of a favorable return on investment; the desired result is economic growth.

FACTORS AFFECTING INNOVATION

The factors leading to the decline in U.S. industrial innovation are not unanimously agreed upon by all segments of society. A group of industry panelists, for example, at the public hearings on the President's Domestic Policy Review of Industrial Innovation pointed to the following factors as being responsible for the decline in technological innovation in the United States: economic and trade policies; environmental, health, and safety regulations; patent and information policy; and regulation of industry structure and competition. Labor representatives at the same hearings pointed to business mergers and interlocking relationships among giant corporations as keys to prices and America's position in the world economy. Public interest groups called for alternative systems of productive enterprise to correct the problem (Lepkowski 1979).

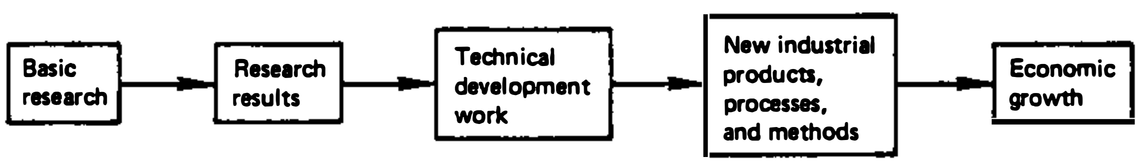

FIGURE 2.1 Popular Perception of the Innovation Process

SOURCE: Haeffner (1973), p. 19

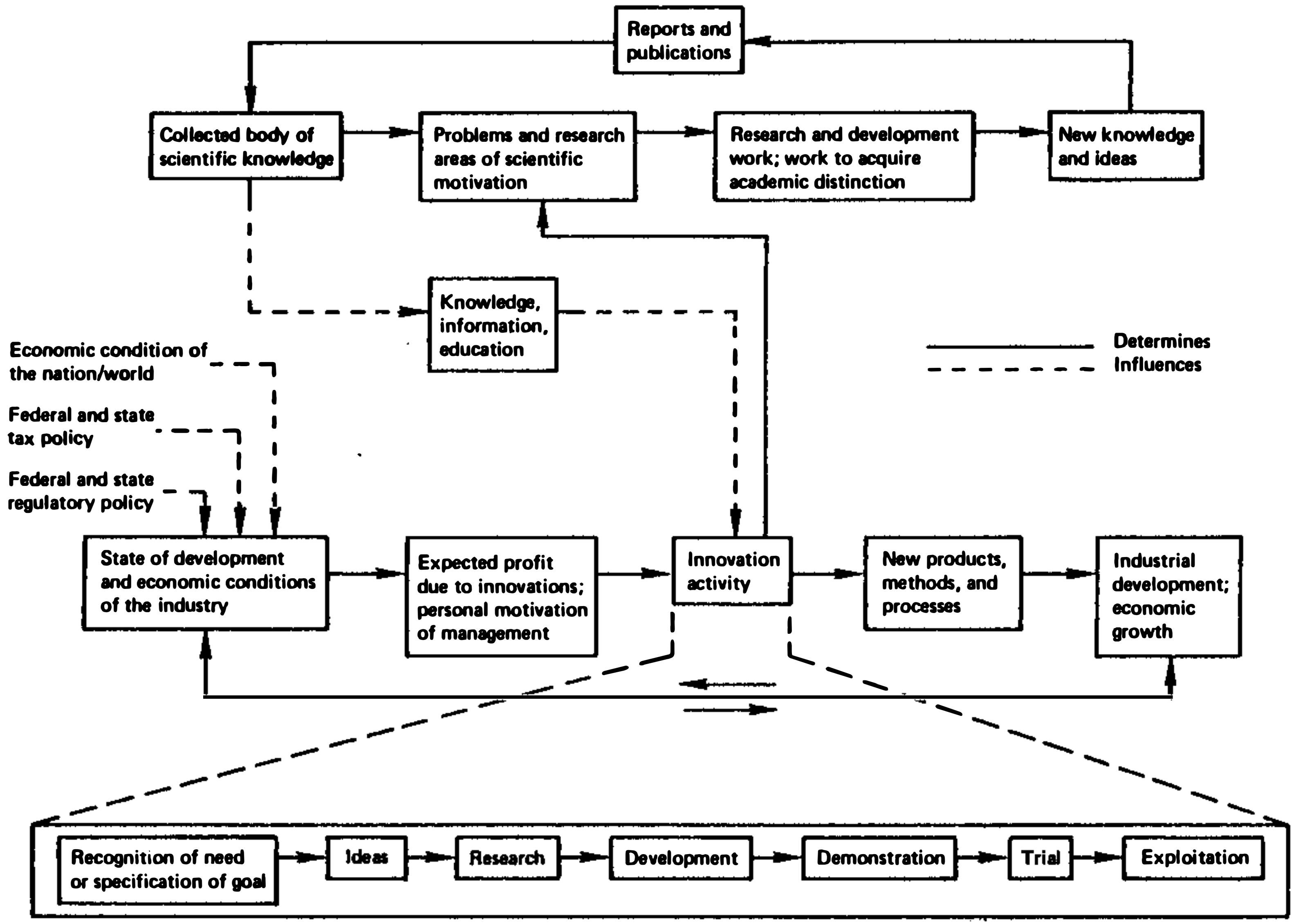

FIGURE 2.2 Technical Concept of the Innovation Process and the Factors that influence it.

SOURCE: Adapted from Haeffner (1973), p. 20

A report of the National Research Council (1979) on the impact of government regulation on industrial innovation shows how federal regulatory policies have an adverse effect on profit expectations, thereby hindering the whole process of innovation from R&D to capital investment in new production facilities. Not only has the level of spending on R&D been affected, however, but what R&D efforts there are have been skewed toward fabrication and uses (where short-term projects can lead to early payoff) and away from ensuring supplies over the long term. The impacts on the mineral industries have probably been more profound and more serious than impacts on most other industries, as evidenced by lagging modernization of plants and equipment, increasing debt-to-equity ratios, and declining profitability.

To clarify why the impact of regulation has been severe on these industries requires: (1) a closer look at the operating characteristics of the mineral industries and their influence on the innovation process and (2) an identification of the policies and actions of the federal government that have discouraged investment.

Characteristics of the Mineral Industries Related to Innovation

A number of the salient characteristics of the mineral industries affect their rates of technological innovation and also affect the force of impact from external forces on their rates of innovation. For analysis purposes the mineral industries can be divided into three generalized types according to the basis of their business:

- Ore deposit-centered industries, where competitiveness of an individual firm depends on the type, grade, and location of its ore deposit (e.g., copper, lead, or zinc).
- Process-centered industries, where competitiveness of individual firms depends on a preeminent position with regard to a technological process (e.g., aluminum); and
- Market-centered industries, where competitiveness of individual firms depends on a preeminent product line or marketing position (e.g., iron and steel).

The operations of companies of each type can be expected to vary according to the nature of the business and how management perceives its goals. But while strategies may vary, the general goals for all industries remain the assurance of satisfactory return on investment and long-term survival.

Ore deposit-centered companies tend to concentrate on discovery and acquisition of new, preeminent mineral deposits rather than on development of new technology. In these companies, a major cost of producing and delivering the primary metal is incurred in the mining phase. Companies can use two approaches in acquiring access of preeminent deposits: (a) exploration for and acquisition of new mineral deposits, and (b) acquisition of known mineral deposits. In the latter case, quite often a company already holding the property is also acquired. Ore deposit-centered companies are more innovative in exploration than in process or production technology. Most of them spend more for exploration and new exploration techniques than for R&D on development, extraction, or processing. Their accounting procedures are also different. For tax and other purposes these companies regard their mine as a profit center and their mill and smelter as cost centers. In other words, the processing operations are regarded as facilities servicing the mine, where the profit is made. The net effect of this distinction, largely psychological, is to concentrate management interest in mine operation and take it away from processing. Recent environmental and other regulatory pressures have tended to divert management attention to meeting regulatory requirements, still to the detriment of developing new process technology. The tendency is less to install a new process than to fix up an existing one, a solution not conducive to technological innovation on a bold scale.

Process-centered companies rely on their capability to produce marketable products from purchased ores and mineral concentrates. Generally the raw material in such industries is a relatively plentiful mineral commodity, which is traded on the open market and represents a relatively small fraction of the cost of producing the primary metal. Some of these industries--such as the aluminum industry--are integrated and control their own production of raw material (bauxite) and intermediate processed material (alumina), often at a foreign location. Given the plentiful raw material supply, more or less available to all who might be interested, competitiveness in these industries is based on process. Companies gain cost advantages by modifying individual processes. In the primary aluminum industry, for example, ALCOA had a clear production cost advantage over other producers until World War II. At that time the federal government forced the sharing of ALCOA technology by awarding the government-built reduction plants to Reynolds Metals and Kaiser Metals. Technical developments by the industry in the 1950s and 1960s significantly reduced the energy and labor requirements for producing primary aluminum as each of the major aluminum producers attempted to improve its share of the market. Meanwhile, ALCOA, continuing its investigation of cheaper aluminum processes, developed the Chloride Reduction Process now in the demonstration stage. The new process, which consumes less energy than the Hall Process traditionally used by the industry, is gaining acceptance (although no commercial-scale plants have yet been built).

Market-centered companies use product development and customer service as the main elements of their growth and profitability. Steel falls into this category. Raw materials are commonly available and openly traded; mature processing technology is used by most companies, and competitiveness is based on level of plant modernization, product characteristics and quality, and marketing effectiveness. While the steel industry is generally considered a part of the primary metals industries, steel firms also offer semifabricated products in a variety of shapes and alloys. Thus, the distinction between metal producer and metal fabricator becomes blurred.

It should be noted that the three categories of mineral industries--mineral deposit-centered, process-centered, and market-centered--are based not on unique characteristics but on conditions under which the industry operates. The base metals industry of Japan, for example, is process-centered, not mineral deposit-centered as in the United States. The Japanese must depend on imported mineral concentrates because their own domestic mines are incapable of providing adequate supplies. They have, in fact, made tremendous investments in sources of supply in other countries, which indicates their consideration of the critical importance of supply. However, all Japanese copper producers are more or less on equal terms from the point of view of their raw material supply. Competition among Japanese companies stems from differences in their process technology, not from differences in raw material positions. Thus Japan has more different types of copper smelters installed and operating today than any other country, and the world looks to Japan for copper-smelting technology.

Similarly, the U.S. aluminum industry has for many years been primarily process-centered even though it had some market-centered tendencies during the 1950s and 1960s. Energy constraints on the industry will undoubtedly keep the U.S. aluminum industry process centered. Location and process will be the determinants of success as energy costs increase. The industry is already making investments in countries where electrical energy can be obtained at lower cost than in the United States, and the aluminum companies can be expected to compete with one another on the basis of energy costs.

The mineral industries themselves characteristically have built-in disincentives to technological innovation. Some of these are:

Nature of the Product

The products of the mineral industries are commodities sold on the basis of availability and price under uniform specification of product form and purity. Prices of the products of the industries, particularly those sold on commodity exchanges, are generally highly cyclical, tend in the short term to be independent of production costs, and tend to be beyond the direct influence of a company or even a large country such as the United States. Thus, added costs, such as those for taxation and environmental controls, cannot be passed on to the customer. In many other industries, such as the electronics industry, new products can create large profitable markets within a few years, whereas a new process in the mineral industries may marginally reduce the cost of production 5 to 15 years hence, when a new plant is to be built or an old one replaced.

Nature of the Raw Materials and Processes

The raw material for a mining company is an ore derived from a mineral deposit, which is, in itself, an anomaly of nature.

Concentrations of groups of elements were created over millions of years in scattered locations by natural processes during the earth's formation and evolution. The competitiveness of a mining company of the ore deposit-centered type depends largely on the size and grade of the ore deposits it owns. Thus, managements of such companies naturally emphasize the exploration function--maintaining their proprietary position by mineral property holdings. The role of R&D in such companies consequently has been to devise new exploration methods and new mineral treatment processes that will allow the economic exploitation of an ore deposit. The amount of R&D in mineral processing has been limited, however, because each type of ore deposit has its own set of characteristics, both in physical and chemical makeup. This has been a disincentive to innovation because new technology applicable to one type of ore deposit is unlikely to be directly applicable to a different type of ore deposit.

Financial Characteristics

The mineral industries are among the most capital intensive in the world. The Cerro Colorado copper project in Panama, for example, involves an investment of nearly $1 billion. The plant that was being considered in Conneaut, Ohio, by U.S. Steel Corporation reportedly would have required an investment of nearly $4 billion. The construction of new facilities involves long lead times: opening a new mine and mill may require 10 to 15 years. This long period combined with large capital expenditures means high risk. Most mineral companies are unwilling to add to the risk by investing in radically new technology.

While not of the magnitude of the full-scale development of a mineral deposit, the investment required to carry a new mineral process through the development and demonstration stages today is large enough to cause most mining companies to think twice before carrying new process ideas beyond the laboratory scale. The size of the investment required was the most common reason given by mining company executives when queried by members of the Committee as to what functions most influenced their decisions regarding new technology.

Manpower

The manpower requirements of the mineral industries span the range from unskilled to highly skilled workers. Particularly to oversee the technological aspects of mineral production, and especially for the generating of new technology, highly skilled technicians and scientists are needed. However, in recent years universities have barely kept up with the manpower needs for industry's operating personnel, let alone provided R&D personnel for the mining industries (Battelle-Columbus Laboratories 1979). Graduate-student enrollment in mineral science and engineering has generally been low and has not improved markedly in recent years. Therefore, the supply of professionals with postgraduate degrees to these industries has been minimal. In fact, not even enough qualified people are being produced to maintain the faculties of U.S. mineral science and engineering institutions. Today, most mining schools are finding it necessary to recruit from Europe, South Africa, Canada, and Australia because of the shortage of U.S. graduate qualified for teaching and research faculties in the United States. These schools are already staffed by faculties that are 30 to 60 percent foreign. The decline in the number of American graduates qualifed for teaching and research in our universities is symptomatic of the broader problems affecting technological innovation in the domestic mineral industries. The National Research Council (1969) addressed itself specifically to this issue in an earlier report. The condition, while somewhat improved, remains essentially the same as a decade ago.

The reasons for the shortages of people with advanced degrees in the mineral science and engineering fields appear to be several. Among the more important is the current strong demand for B.S.-level engineers at salaries that are high, and that lure B.S. graduates into immediate employment in preference to postgraduate study. Equally important is company philosophy, which has emphasized short-term projects promising early returns on investment and avoided company commitment to long-term R&D programs for which personnel with advanced degree are required. In short, operating experience is held to be more important to a company than is technical training. The net result is that students have little interest in seeking postgraduate degrees in the mineral sciences and related fields. Many of the enrollment problems of graduate degree programs in the mineral resources disciplines in universities would be solved if employment opportunities were available that utilized the special skills obtained through graduate study. While the mineral resource science and engineering disciplines have traditionally experienced this problem (NRC 1969), other disciplines, such as chemical engineering, are today finding themselves in a similar position (Heylin 1981, Worthy 1981). It follows that with limited employment opportunities for Ph.D.-level graduates there will be a limited supply of Ph.D.'s available to assume faculty positions in universities--a phenomena that will exacerbate the manpower problem further.

Company Organization and Philosophy

Most mineral companies are staffed primarily for operations. They generally have not been organized and staffed for research and development activities. Undoubtedly companies have evolved such organizational structures and philosophies because of the nature of the industry and the maturation that has occurred over the last 30 to 50 years. There are examples of successful exploration by one company uncovering new sources of high-grade ore and thereby undercutting successful R&D by another company on processes designed to use marginal ore. Furthermore, because many U.S. companies depend on the possession of a superior ore deposit to maintain their competitve positions, there is a reluctance to develop process technology for marginal ores because it might be used by a competitor to convert a previously unminable deposit into a profitable one, thereby giving that competitor a more favorable position in the mineral market. Thus, past priorities of the industry have established a management pattern that is not conducive to facing the problems of the future through the technology option. That R&D practiced is of a short-term, problem-solving nature, aimed at an immediate return on investment.

Technology Transfer

Processes and equipment used in mining and mineral processing are for the most part not proprietary. New technologies are more often purchased in the form of equipment and chemicals from suppliers than developed by the mining companies themselves. Because of perceptions of overall risks, including technological risk, mineral companies have been reluctant to try technologies that have not been proved elsewhere. Suppliers to the mineral industries, on the other hand, develop incremental new technology to provide a competitive edge in their own businesses. Such incremental advances as are developed are therefore spread through the mineral industries by this form of technology transfer. Even these incremental advances have not been fully exploited in recent years because of the poor capital formation performance of these industries. The ease with which technology is transferred within the mineral industries tends to discourage individual companies from embarking on programs for developing proprietary technology.

Policies and Actions of the U.S. Government Influencing Innovation in the Minerals Industries

In recent studies of innovation in U.S. industries, a number of disincentives have been identified as stemming from the U.S. government's policies and actions, and these are frequently aggravated by similar actions of state and local governments. The general picture is described by Dee (1980) as follows:

> A major cause of the decline in productivity in the United States has been federal policies and regulations that discourage investment in research and development. . . . In addition, technological innovation is burdened by an unfavorable, if not hostile, regulatory climate.
>
> In a message announcing his industrial innovation initatives late last year, President Carter acknowledged that government has placed 'stifling restraints' on innovation. He expressed the need for government to form a 'close partnership' with the private sector to restore the innovative nature of the American free enterprise system as one of the most precious resources of our country.

> . . .Science and technology are our nation's fundamental resources. Government's role should be to nurture these resources, not to suppress them.

Environmental Regulations

It is the opinion of the Committee that environmental regulations are having a profound effect on the mineral industries of the United States. The effort toward innovation is reduced by the diversion of R&D manpower and money to coping with environmental problems and by delays in capital budgeting caused by the uncertainty of future standards. As noted by Atkinson (1980):

> Environmental groups urge the agency [EPA] to enforce strict controls. EPA's detractors argue that regulations are established arbitrarily to meet legislative deadlines and are based on inadequate scientific and technical information. Until recently, there has been little consideration of the economic cost and social impact of environmental protection. The implementation of regulations has become characterized by adversary relationships that inhibit objective use of the best scientific data available and the development of technically optimal solutions.
>
> Remedies have been attempted. In 1977, the National Academy of Sciences undertook a study of decision-making at EPA; some of its recommendations have been implemented. President Carter issued an Executive Order in 1978 instituting specific steps to improve regulation. The General Accounting Office published a report in 1979 on improving the use of scientific and technical information at EPA. There are currently at least three bills under consideration by Congress on regulatory reform and risk assessment.

Energy Availability

In the seven years following the OPEC embargo, federal and state governments in the United States have not reached a clear decision on energy policy. Energy conservation is in itself a spur to innovation, but owing to lack of decision on national goals, choices of fuels, development of alternatives, acceptable standards, stable regulations, and on other policy matters, technical efforts are diffuse, often short term, and sometimes misdirected.

Plans for mining, mineral processing, and subsequent manufacturing operations must be based on assured supplies of energy. The mineral industries have been estimated to consume as much as 10 percent of the energy used in the United States (DOE 1977). Design of mines, mills and smelters involve complex trade-offs between the energy costs, other operating cost, and capital investment. Uncertainty over energy availability and prices confuses attempts to optimize designs, delays investment decisions, and hence postpones the final steps in the innovation process.

Safety and Health Regulations

Uncertainty with respect to safety and health standards and the prospect of increasingly restrictive regulations for an indefinite period into the future are delaying, if not stopping, investment in some parts of the mineral industries; e.g., those industries producing lead, zinc, and copper. Opportunities for adopting (or even experimenting with) innovative technologies are thereby forgone, and existing plants are often modified only to comply with regulations. At issue is not the desirability of safety and health standards but the manner in which the standards are developed, promulgated, and enforced.

Antitrust Regulations

Cooperative R&D programs among companies within the mineral industries as well as other industries have been retarded by confusion over antitrust statutes. An NRC report entitled "Antitrust, Uncertainty, and Technological Innovation" (NRC 1980a) pointed out how the perceptions of antitrust statutes by legal advisors to corporations have retarded cooperative research programs. That and other reports during the White House domestic policy review of industrial innovation in 1978 and 1979 showed a need to clarify antitrust statutes to provide guidelines for U.S. companies interested in developing cooperative R&D programs. As a result, the Department of Justice prepared a report dated November 1980, entitled Anti-Trust Guide Concerning Research Joint Ventures (USDJ 1980). One of the purposes of this report was to clarify the position of the Department of Justice on collaboration among firms in conducting R&D to help make sure that antitrust laws are not "mistakenly understood to prevent cooperative activity even in circumstances where it would foster innovation without harming competition."

In the guide, the department points out that there are many sensible reasons for research to be conducted jointly by two or more firms, by an association, or by joint venture. It also acknowledges that antitrust issues can arise from such research because the results could lead to "market dominating" technology, because the research could be conducted by competitors or potential competitors, or because there may be restrictive agreements relative to the results. The guide provides "an analytic approach" to evaluating the legality of joint research projects and restrictive clauses. The analysis indicates that there are four general conditions or situations that influence the department's judgment of legality: (1) the nature of the proposed research, (2) the characteristics of the joint venturers, (3) the characteristics of the industry, and (4) collateral restrictions upon the venturers or outsiders. No attempt will be made here to summarize the details of the department's analysis of these four major points.

It is sufficient here to point up that guidelines are available. Furthermore, a number of case examples are used in the guide to interpret the analysis presented.

Even prior to this clarification, companies in some sectors of the mineral industries had successfully organized cooperative R&D programs. Then as now it appears that the problem of antitrust regulations may be more one of perception than reality. It is important therefore that leaders of the mineral industries vigorously pursue opportunities to reduce R&D costs through cooperative programs. It is also important for the Department of Justice to continue to clarify and interpret the published guidelines as they affect on the mineral industries.

Fiscal and Monetary Policies

All capital-intensive industries are severely affected by the present rate of inflation in the United States. Because of federal tax policy, depreciation rates have not been sufficient to replace plant and equipment in capital-intensive industries like the mineral industries. Inadequate depreciation and the decreased ability of companies to generate capital internally have retarded the adoption of new technology in the mineral industries.

U.S. Trade Policy

In recent years, a number of domestic industries have been displaced by foreign competition. For example, thirty years ago the domestic steel industry produced nearly half of the world's steel and the United States imported a negligible amount; in 1979, the United States produced only 15 percent of the world's steel and imported about 20 percent of the steel it used. U.S. production has grown only modestly. Many in the mineral industries believe that exports of foreign steel to the United States fall within the legal definition of "dumping" (see the Anti-Dumping Act of 1971 and the Trade Adjustment Act of 1976). Dumping refers to the sale of a foreign-produced product below the price it sells for in the country of manufacture. The dumping price can even be below the average cost of manufacture inasmuch as incremental costs near plant capacity are less than those at reduced capacity. The governments of many countries producing and exporting mineral-derived commodities have continued to support growth policies for their mineral industries. This raises the question of whether commodities produced overseas with these relatively inexpensive raw materials are in a sense being "dumped" in this country as well.

Actions of Other Governments Influencing Innovation in the Mineral Industries

Actions of foreign governments, too, have had negative impacts in recent years on innovation in the U.S. mineral industries.

Nonmarket Actions

In some developing countries, governments have chosen to maintain production of commodities despite falling demand and prices. Such actions have created uncertainty regarding the possibility of future actions that run counter to concepts of a normal economic market. As a growing number of developing countries build their own mineral producing and processing industries, the likelihood of such actions increases. When mineral production accounts for a significant proportion of the gross national product, there are intense pressures on the political structure of the country against closing mines and laying off workers in response to softening mineral-commodity markets. The tendency is to overproduce (see Hardin 1968) and thus to drive world commodity prices down still further, thereby damaging the industries of the producing country itself as well as those of developed countries.

Community Investment

In the past, remote mineral deposits were developed only if a company could justify, on the basis of competitive economics, the investment in roads, housing, hospitals, ports, and other community services in addition to the mining facilites. But foreign governments may now choose to make such investments in new communities for political rather than economic reasons, and the price of minerals mined in these circumstances may not reflect the delivery costs. Such an influence by foreign governments increases the risk of investments in domestic properties.

3. ENCOURAGING INNOVATION

Technological innovation is a process by which change in production techniques and products is brought about. Maintaining the capacity for change is an indispensable feature of industrial survival, and thus technological innovation should be part of the business strategy of any company relying on technology. Unfortunately, for a variety of reasons, the domestic mineral industries as well as other sectors of American industry have fallen behind in technological innovation.

Technological innovation does not occur spontaneously but must be planned for in the operations of a company. As we have already noted, there are barriers to technological innovation in any industry. If innovation is to be initiated and to succeed, the business climate in which the industry operates must encourage decision makers to plan for technological change with some confidence that it will succeed and yield a return on investment of time, manpower, and capital equal to or better than an investment in other strategies.

Although innovation in the mineral industries is the focus of this report, the problems are generic to science, technology, and industry over a broad front (see Baruch and Clauser 1978; David 1977, 1979; Hatch 1978; Lederman 1978; Manners and Nason 1978; Mattson 1978; Staats 1976) and have received much attention. No easy solutions to technological innovation problems have been forthcoming because of the complex interaction of economic factors, governmental regulations, and attitudes that have taken root over many years. These factors have combined to create uncertainty about the future and inhibit long-range planning and investment.

ISSUES OF ATTITUDE

Earlier it was pointed out that depressed economic performance has spawned a conservative industry management, which views new departures as risky and investigates change cautiously. To them, bold approaches appear simply too expensive.

Management is dominated by people for whom operating experience carries more weight than technical training. Recent graduates, although well paid, are all too often assigned to jobs that make less than optimum use of their formal training. The mining industries are thus not generally seen by American students as an exciting, rewarding place to work. The mining schools of the United States are increasingly filled by foreign nationals, who are receiving valuable training and applying it in their native countries.

Vendors of reagents and equipment, asked for observations about the mineral industries, have reported more willingness to experiment and more technological competence among mining organizations in such countries as Chile, South Africa, and Australia than in the United States. Management attitudes in U.S. industry by comparison often seem cautious, even reactionary, and not conducive to innovation. The Bureau of Mines also seems to suffer from a certain malaise, caused perhaps by bureaucratic layering but more probably by the necessity of dealing with red tape instead of working on substantive issues. Universities, which relate to both industry and government, cannot escape the same feelings of frustration due to the lack of interest on the part of both government and industry in funding mineral technology programs.

An important element in the restoration of the vigor of domestic industries will be leadership. To remove the mistrust that currently frustrates efforts to correct industry vulnerabilities, leaders must educate policy makers about the economic, technical, environmental, and social limits on federal policy with regard to mineral raw materials.

In reviewing the outlook for the 1980s for industrial research as a whole, David (1980, p. 133) stated:

> The evolution of industrial research in the 1980s will depend on an interplay of forces, private and governmental. But a central factor will be corporate attitudes toward innovation. These will determine the market for new technology. That market in turn will hinge on the economic health of industry.

ECONOMIC CONSIDERATIONS

The economic setting within which the mineral industries are operating has been described by Etzioni (1980) as follows:

> We have overburdened our industrial machine, the modern American economy, that previous generations labored to put together. We have indulged in overconsumption (public and private) and underinvestment. This is reflected in most, if not all, components of the industrial system: weakening of transportation systems, inadequate development of new energy sources, declining innovation rate, low savings rate, rising obsolescence of equipment and plants in several key industries, less satisfactory preparation of the labor force, and so on.

Anyone who puts available funds at risk looks ahead to a sufficient return on investment to justify the risk taken. Commodity companies that are most attractive to the careful investor have a consistent record of long-term growth in earnings and dividends. Over a period of time, the market value of the stock may fluctuate, but historically it has maintained a favorable relationship with respect to the value of alternative investments. The failure of the United States to develop long-range mining and mineral processing policies and mechanisms to adhere to those policies impairs consistency and, ultimately, capital formation and makes it very difficult for the mineral industries to plan new domestic programs, particularly if large amounts of capital are required.

Even if a federal policy were well defined in the near future, it would be difficult for the mineral industries to develop new domestic programs quickly, because of the need to develop the capital and cash flow necessary to encourage bold long-term R&D and innovation. In the nonferrous mineral industries, R&D is mostly development, requiring large sums for demonstration of smelting and refining projects. The demonstrations have a history of frequent failure because of the difficulty of scaling up small research and pilot units to production scale. In the absence of a long-term mineral policy, the uncertainties are too great to expect a prudent management to risk large amounts of the stockholders' money on R&D.

Only by sustained, favorable economic performance can the companies attract the engineers, scientists, and managers necessary to bring about a fundamental change in these industries (Bagge 1979). Government, both national and local has a role to play in stabilizing the economy to make such performance possible. The Industrial Research Institute (1980) suggested that government policy in this role should be directed toward influencing <u>decisions</u> to innovate rather than the <u>ability</u> to innovate, and that such policy should be designed to remove disincentives rather than to intervene directly in the innovation process.

H.R. 1053, the Capital Cost Recovery Act, which has been introduced in the 97th Congress, would provide incentives to the mineral industries by accelerating the rate of depreciation, allowing write-off over 10 years on buildings, 5 years on all machinery and equipment, and 3 years on the first $100,000 invested annually in small trucks and automobiles. The shortening of "asset guideline life" schedules would benefit the mineral industries. A similar bill, or a modification to fit requirements specific to the mineral industries, would help to improve the economic performance and thereby improve the atmosphere for innovation.

Another incentive would be a modification of tax rules to permit including as an expense the cost of pollution-control equipment as it is purchased and installed. Although initial impacts would further depress profits, the long-term effect would be beneficial to the stability of the industry and at the same time would aid in the achievement of environmental goals required by society.

A third type of incentive would be a tax credit (or a form of matching grant) for grants made to universities for R&D. Congressman

Charles A. Vanik of Ohio submitted a bill to the 96th Congress that would give a tax credit amounting to 20 percent (or perhaps more) of the grant made. This approach could be helpful to the mineral industries, especially if long range and sustained plans were developed for continuing relationships with academia. No new institutional arrangements would be required: with the incentive of a tax credit for university-conducted R&D for publication, the more innovative companies on their own could establish relations with the universities best suited to address problems of mutual interest, while at the same time the industry as a whole could benefit by publication of the findings of the R&D.

A refundable tax credit for R&D expenses would carry the tax credit approach further: if a company did not have the income against which to take the credit, a graded or graduated scheme might be used under which the government would make at least a token payment on the difference. This would prove useful for new concerns getting started but not yet profitable.

Added incentive for more complete mining of a deposit could be provided by allowing the early write-off of mine-development expenses and a more rapid write-off of capital expenses.

The concept of pollution fees has never had much support either from American industry or from environmentalists, who see such fees as a license to pollute. In view of European and Japanese experience, however, this concept might be reexamined. A "carrot and stick" approach could be worked out. For instance, a standard for emissions could be set, above which fees would be determined by a nonlinear formula; the maximum sanction would force shutdown of the plant. Credits for reducing emissions below the standard would also be determined by a nonlinear formula. The maximum annual credit, to be given if the emissions were zero, might equal the annual allowed depreciation of the facilities installed for pollution abatement or for conversion to a nonpolluting process.

Products that result in greater than average profitability often turn out to be sustained by better-than-average R&D support, both within and outside the mineral industries. Bold innovation relates to economic success more often than not. But responsiveness to innovation is not always obvious, and it often requires unusual confidence in a favorable outcome to allocate high R&D budgets to low-profit projects.

It is important to examine the relative long-term performance of a company by product group or by "profit center." Some units within a company may be productively innovative, but their capabilities may be hidden by less innovative units. The individuals concerned with the more successful units can be important sources of expertise for expansion of the innovative process.

Patents have not been heavily relied upon within the mineral industries, because the industry does not generally view licensing of technology as an important component of its cash flow. Furthermore, the long development time for many mining and mineral processing projects allows relatively few years of commercial operation under the protection of a patent. The U.S. Bureau of Mines (1976) has documented projects that have required more than the 17 years afforded patent protection just to pull together the financial arrangements. Process patents are few and characteristically difficult to enforce, although notable exceptions do exist. Vendors of reagents and, to a lesser extent, vendors of equipment for the mineral industries are more aggressive in obtaining patents on their products. Some ways of altering the patent system to encourage the mineral industries to innovate are noted below.

The Report of the Subcommittee for Patent and Information Policy of the Government Domestic Review of Industrial Innovation (U.S. Department of Commerce 1979) contains the following proposals pertinent to the mineral industries:

- Reduce the cost of patent litigation.
- Provide a specialized patent court for patent cases.
- Transfer commercial rights to government-sponsored research to the private sector.
- Extend patent terms to compensate for delays in commercialization caused by government regulations.
- Encourage other countries to give U.S. innovators enforceable patent rights.

Costs, uncertainties, and delays resulting from the large number of laws and regulations involving environmental, safety, health, and consumer protection have been pointed out as a major cause of diversion of effort away from innovation. In recent years there has been unprecedented conflict among the government, the industry, and public-interest groups over these laws. The economic impact of compliance on the industry has been substantial and continues to grow as more regulations are promulgated. A better understanding of priorities would allow industries to predict more reliably what the true cost will be and when. The uncertainties need to be resolved as soon as possible, because they paralyze the decision-making process and postpone purposeful activity.

Another area of uncertainty is the mineral supply posture of the United States. This has been at issue for the last several decades and, in spite of the passage of the Mining and Materials Policy Act of 1970 we appear to be no closer to the definition of a national mineral policy. Despite the lack of a clearly defined national mineral policy, it is certain that we will continue to have a dependence on foreign imports for certain mineral commodities. The important question is, to what extent should we attempt to be self-sufficient in mineral commodities for which we do have domestic sources? Unfortunately, this question cannot be answered until a national mineral policy is explicitly defined.

Although the optimal policy for a company may in many cases coincide with the interests of the nation or the world, they will not invariably do so. Without a firm definition of national policy a company may well seek to improve its own financial position to the detriment of the nation. Resolution of national policy issues is urgently needed so that industries can proceed with sound expectations concerning government actions and so that the appropriate direction of government involvement can be decided.

Other countries can serve as useful examples in considering these decisions. Japan, for example, must import almost all of its mineral concentrates, but until recently it has elected to maintain smelting and refining operations within the country. Japanese policy thus provides for flexibility with regard to raw-material sources but absolute control of processing. The success of Japanese mineral industries can be attributed in part to Japan's well-defined national policy.

INSTITUTIONAL ARRANGEMENTS

A large variety of institutional approaches to technological innovation are possible, including the establishment of a new centralized government-supported research organization such as exists in other countries. At the outset, however, we should consider the use of present institutional structures rather than the creation of new ones, if for no other reason than that the use of existing institutions would be lower in overall cost than a new centralized organization.

The Bureau of Mines has played an important role in the past in the technological evolution of the mineral industries. There has been close cooperation, particularly on a professional level, between key researchers of the Bureau and in the mineral industries. But while professional relationships continue between Bureau and industry personnel, institutional barriers restrict many cooperative arrangements that were possible in the past. In recent years the Department of the Interior, in accordance with administration policy, has emphasized a regulatory approach designed to conserve natural resources; this has had a restrictive effect with regard to mineral development on public lands. A different policy seems now to be contemplated. The Bureau of Mines' mineral supply mission in certain respects represented a conflict of interest within DOI which inhibited both the mineral-development activities of the Bureau and the Bureau's relations with industry.

Equipment manufacturers and reagent suppliers formerly were able to work in the facilities of the Bureau to gain the necessary process data from mill runs or demonstration trials. Projects could be discussed and addressed openly with a minimum of red tape. Today, lengthy negotiation is required before cooperative trials can be established; trust between parties has declined; the sense of urgency is hard to maintain; and organizational structures and procedures are more difficult to cope with. Past accomplishments of the Bureau of Mines are admired by leaders of the mineral industries, but many of those leaders believe the Bureau has weakened in recent years.

One option for improving mineral R&D is to reestablish the pluralistic and less formal relationship between industry and the Bureau of Mines that existed in earlier years. The Bureau could be involved in trilateral projects of universities, government, and industry, either as a participant or a peer review organization to judge the appropriateness of projects for cooperative research, as the Federal Energy Research Commission scrutinizes research by the Gas

Research Institute (see Chapter 5), although the Bureau would not be expected to have the regulatory control over such projects that the FERC does. Another advantage of using diverse institutions rather than a new centralized one is that companies and universities would retain a good measure of freedom in choosing projects to support and the manner in which they are to be operated, with less necessity of compromising with other participants. A disadvantage of not choosing a centralized institution for mining and minerals R&D is the comparative lack of visibility as a progressive initiative and the very real threat of benign neglect and lack of leadership due to the dispersion of effort. Further, the companies involved must have incentives to participate in pluralistic activities.

There is a precedent for government-industry cooperation in the Department of Agriculture's support services for the American farmer, ranging from government laboratories to land-grant universities and their experiment stations and extension services. This assistance was originally intended to help the small farmer, and the fact that today's agriculture is largely agribusiness is sometimes used to argue against the USDA research programs. Nevertheless, the results of the cooperative arrangement are obvious: the United States leads the world in agricultural production and productivity. The Department of Commerce has compared the relationship between USDA and the American farmer to that between the Japanese Ministry of International Trade and Industry (MITI) and Japanese industry (F. Haynes, quoted in Robinson 1980); and the efficiency of this cooperative arrangement is similarly evident in Japanese production and productivity.

The involvement of universities in cooperative projects with industry has received support from the National Science Foundation, as described in Chapter 4. A review of industry-university cooperative research (Erving 1980) revealed mixed opinions on the value of such projects. There is some question whether universities can maintain their traditional independence if they become involved in short-term projects for the benefit of particular companies. Generic problems, such as energy reduction through improved grinding processes, which do not bind the university too closely to the problems of specific companies, would be the most appropriate focus for such cooperative research. It is important to maintain clearly the respective identity of industrial, academic, and governmental institutions.

Opinions are also mixed regarding institutional changes that would increase the federal government's involvement in research, development, and demonstration for the domestic mineral industries. A central organization such as a "national institute of mineral resource technology" for the United States, for instance, would be a major undertaking with massive government involvement. A centralized approach on such a scale, however, is no guarantee of innovation, sustained high quality R&D, or successful application of findings. Economic incentives designed to disperse rather than centralize the national effort may yield greater success through diverse centers of excellence in universities, industry, and government.

The Gas Research Institute and the Electric Power Research Institute, described in Chapter 5, are currently quite successful in joining different companies in common R&D programs. But their products, gas and electricity, are under price controls. These industries therefore have some certainty of recovering costs and benefiting from research under the protection of a controlled rate structure, while the public is not in danger of losing the benefits of competition, since the utilities are already noncompetitive. The metal and mineral industries are not regulated and are competitive: mineral companies are therefore apprehensive both about recovering R&D costs and about antitrust regulations. In an unregulated industry there is more reason to be secretive about process advantages, whatever the source of technology.

It may thus be unrealistic to expect companies in a free market to join enthusiastically in institutes or consortia to conduct process research. Because there are reasons of public interest for them to do so, it should be possible to develop an understanding with the Justice Department that would allow well-defined, cooperative projects to be carried out. The recently released Antitrust Guide Concerning Research Joint Ventures (USDJ 1980) seems to bear this out. Generic problems at the basic production level would probably be more appropriate for cooperative research programs than product-oriented research. Involvement of the government in a consortium could help maintain a R&D momentum in spite of the cyclical nature of the industry.

OTHER ACTIONS

During the course of this committee's study, the executive branch of the federal government conducted a Domestic Policy Review of Industrial Innovation. The review was made in parallel with a Domestic Policy Review of Nonfuel Minerals. Although the industrial innovation study did not specifically address itself to technological innovation in the mineral industries, it did address problems and issues generic to all of American industry.

The following recommendations of the President (Executive Office of the President 1979) resulted from the innovation review:

- Enhance information transfer by establishing a center for the utilization of federal technology.
- Increase technical knowledge by establishing nonprofit centers at universities and elsewhere in the private sector to develop and transfer generic technologies.
- Strengthen the patent system by establishing a uniform patent policy.
- Clarify antitrust policy.
- Help small innovative firms by expanding NSF's Small Business Innovation Research Program.
- Open federal procurement to innovations.
- Improve the regulatory system by substituting performance-based standards for design- or specification-based standards.
- Help labor and management adjust to technological change by developing a Labor/Technology Forecasting System.

- Maintain a supportive climate for innovation by hosting national conferences on innovation, making presidential awards for technological innovation, and forming a committee to monitor innovation.

The response of the private sector, through the Industrial Research Institute (1980), was that, while the President's recommendations included initiatives to remove many of the structural barriers to innovation and served a useful purpose in calling attention to the decline in U.S. innovation, they fell seriously short of proposing the economic incentives needed for industry to follow through on the entire process of innovation. The Industrial Research Institute made its recommendations for federal action designed to bear on the decision, rather than the ability, to innovate. The position of the Industrial Research Institute is that industrial innovation is a natural and potent force in any free market economy and that specific interventions by the federal government should not be required. What is required instead are a number of federal actions to remove economic barriers and disincentives to successful innovation. Such actions would include (Haas 1980):

- Controlling inflation.
- Increasing capital formation
  -- by modifying corporate income tax policy;
  -- by further decreasing the capital gains tax; and
  -- by further increasing depreciation allowance and/or investment credits.
- Subsidizing socially important innovations.
- Being cautious in the use of subsidies in lieu of economic incentives.
- Using economic regulatory incentives.
- Using government procurement to aggregate markets and set innovative performance standards.

Although the views of the Industrial Research Institute are generally those of industry, the Committee believes that the specific actions identifed above are appropriate and significant, and that implementation of these actions could lead to positive results in the solution of technological innovation problems in the mineral industries.

4. ROLE OF THE PUBLIC SECTOR

The Massachusetts Institute of Technology Center for Policy Alternatives discusses the role of government in the industrial innovation process in a report to the Office of Technology Assessment (OTA 1978). MIT's findings show that governments may choose to intervene in technological development when market forces are clearly incapable of achieving defined national objectives, as in the following circumstances:

- when private economic units cannot capture all the benefits arising from the creation of new knowledge. Economic units tend to invest only in those projects whose results they can control and use; in some cases, such as public health, few economic units benefit from research investments.
- when the limited scale of the private economic units involved prohibits their undertaking R&D that requires vast resources.
- when the public interest requires a government role to shape and control the social and political nature of new technological development. It is perhaps not appropriate to expect the private sector, which responds more to market signals than to social priorities, to invest on its own in R&D in such areas such as pollution control and transportation facilities for the elderly and the handicapped.

The MIT group points out that government regulation is one form of intervention to correct the failure of the marketplace to respond to public needs and that such government intervention may or may not be beneficial to the industry involved or to society in general. Timing, interaction with other programs, and the details of implementation are often crucial.

Intervention by the U.S. government is not unique, as Pavitt (1976) showed in his study of the industrial innovation process in France. Pavitt's list of reasons for intervention by the government of almost any industrialized nation is more extensive than MIT's, although there is some overlap:

- inability of industrial firms to appropriate adequate benefits of R&D for themselves, resulting in an underinvestment in R&D.
- indivisibilities in the performance of research, which inhibit any one firm from pursuing a research project.
- short time horizons of industrial managers in relation to the long time spans required for R&D.
- aversion on the part of industrial firms to the risks of R&D.
- inability of technically backward industrial firms to help themselves.
- large-scale development requirements that are beyond the capacity of the industrial sector, yet which are advantageous to society at large.

The Committee contends that all these reasons are applicable to the U.S. mineral industries.

Public sector involvement in technology development is not a new concept. The Morrill Act of 1863 was an expression of the federal government's support for general technological innovation in the private sector. This act enabled the direct grant of federal monies to state-operated colleges to promote the agricultural and mechanical arts and to train their practitioners. A version of this form of federal financial assistance to state universities has been authorized by Title III of the Surface Mining Control and Reclamation Act of 1977 (PL 95-87). Unfortunately, sufficient funds were never appropriated to implement this provision of the Act to the extent intended and funds have not been requested for the program in 1982, even though very encouraging results have been obtained. Experience has taught us that such programs cannot be expected to produce short-term benefits and must be considered foundations to be supplemented by programs directed at more narrow goals. The agriculture extension programs accompanying each land-grant college agriculture program are major vehicles for such follow-on technology development and application.

In recent years, the most prevalent form of public sector involvement in technological innovation has been the direct federal financial support of R&D in the private sector. The U.S. government supports a considerable portion of the R&D performed by industry in this country (37 percent overall in 1975, but as much as 46 percent in electrical equipment and communications and 79 percent in aircraft and missiles) (NSF 1977). This R&D not only affects the state of the art in many technologies but also is an important determinant of international trade patterns and industrial organization.

This effort both to stimulate and to direct industrial R&D efforts has not always been effective. It has spawned many private-sector organizations that produce not products or processes for public benefit but technical reports for the use of federal decision makers. Federal support of private-sector R&D has been met with mixed reactions from numerous investigators who have examined the subject.

Blank and Stigler (1957) discuss the consequences of government funding of R&D performed by private organizations in terms of "pump-priming/substitution." At one extreme, a private business that takes on government research contracts becomes persuaded of the benefits of research and embarks upon private research as well; thus, the government contracts serve a pump-priming function. At the other extreme, research that a business had been conducting on its own is simply shifted to public contracts, and federal monies are substituted for private monies, so these contracts constitute no net additional contribution. Of course, both of these extremes are improbable, but so too is the intermediate situation in which exactly the amount of publicly funded research is added to total research. Ordinarily, of course, corporations pursue R&D as a means to a commercial end, namely the manufacture and sale of a profit-generating product--they do not do R&D for R&D's sake.

Betsy Ancker-Johnson, former assistant secretary for science and technology, U.S. Department of Commerce, has said that technological innovation represents the "novel aggregated methods for providing previously unavailable goods or services or already available goods or services at lower cost in money or natural resources" (Ancker-Johnson 1977). She has described the aims of federal policy on technological innovation as:

- the production of technology significant to the national economy;
- the diffusion and exploitation of technology significant to the national economy; and
- the diffusion and exploitation of technology for international advantage.

The ways in which the federal government can work toward these goals are listed in Table 4.1. Clearly, there are many options open to the government beyond mere support of R&D to influence technological innovation in a domestic industry.

Elmer B. Staats (1976), the former comptroller general of the United States, has pointed to the need for a more constructive partnership between industry and government in the area of technological innovation. In his opinion, federal financing of applied R&D in support of commercial technology should be considered in the context of potential economic and social benefits to the nation, in relation to the private sector's ability and motivation to invest its own resources, and in relation to other government initiatives that can influence the climate for private sector innovation. He points out that most of the other industrialized nations of the world have developed closer relationships between government and the private sector with regard to capital formation and R&D, and that we should explore new possibilities for government-private sector interaction within the framework of American institutions. Staats also points to the need for closer cooperation among federal agencies--the Internal Revenue Service, the Securities and Exchange Commission, the Justice Department, and the Department of Commerce--if improved productivity and advances in science and technology are to take place.

As the MIT study for OTA found, direct federal support for technological innovation has traditionally taken one of two forms in this country: general support for basic research, such as that funded

TABLE 4.1 Possible Federal Technology Policy Options

A. ANALYSIS AND PLANNING

B. PRODUCTION OF TECHNOLOGY

Resource assurance
1. Skilled S&T manpower development
2. Stable and adequate basic R&D support

Provision of proprietary rights
3. Patent law revision

Federal support of industrial R&D: direct
4. Interest-free or low-interest government loans for industrial R&D
5. Grants for generic industrial R&D

Federal support of industrial R&D tax measures
6. Increase in investment credit for R&D plant
7. Increase in depreciation allowances for R&D plant
8. New tax credits or equivalent cash payments for industrial R&D
9. Tax credits or cash payments for industrial R&D expenditures, not plant
10. Tax credits or cash payments for incremental industrial R&D
11. Tax credits or cash payments for incremental industrial R&D in chemical and capital goods industries
14. Social cost/benefit analysis of proposed regulations
15. Manpower retraining, relocation and pension program
16. SEC study of the effect of corporate remuneration policies on innovation.

Creation of new technical enterprises and aid to independent inventors.
(a) Direct financial aid
17. National Research and Development Corporation to finance innovative activity of individual inventors
18. Preferential treatment to new technology enterprises in government contracts
19. University small technical enterprise associates
20. Free patent protection

Creation of new technical enterprises and air to independent inventors:
(b) Indirect financial aid
21. Assurance of venture capital availability for new technical enterprises
22. Government guarantee on SBIC loans to new technical enterprises
23. More generous capital gains tax treatment
24. SBIC's incorporation under Subchapter S or as partnerships
25. Increased liquidity through SEC and IRS modifications
26. More favorable founder stock option incentives
27. Tax deductibility of investments in new technical enterprises
28. Graduated corporate income tax rate structure
29. Use of government infrastructure services

C. DIFFUSION AND EXPLOITATION OF TECHNOLOGY DOMESTICALLY

Information diffusion
1. Gathering, organizing, and disseminating scientific and engineering information
2. Educational publications on consequences of major technology changes
3. Science court to establish credibility of scientific information
4. Provision of information to state and local governments
5. Consumer technology information services
6. Enhanced NBS voluntary performance standard effort

Federal support of commercialization
7. Funding for commercialization of selected government inventions
8. Funding for commercialization of socially desirable private inventions
9. Stimulation of innovation through Federal procurement policy

Reduction of barriers to innovation
10. Patent law revision
11. Federal patent policy
12. Modification of antitrust laws to allow cooperative R&D
13. Determination and modification of regulations inhibiting innovation

D. DIFFUSION AND EXPLOITATION OF TECHNOLOGY FOR INTERNATIONAL ADVANTAGE

Improvement of U.S. competitiveness in international trade
1. Policy statement on free flow of publicly available data
2. Limit of decrees on compulsory licensing to domestic availability
3. Increase of U.S. effectiveness in international standards-setting
4. Improved control of design and manufacturing technology
5. National benefit equilization tax
6. Disallowance period of seven years for export of technology, per se, developed with Federal funds
7. Transfer of technology, per se, to Eastern bloc only through "Techport"
8. Expansion of export promotion programs

Technological support of lesser developed countries
9. Business code of behavior
10. Establishment of bilateral commissions
11. Organization of multilateral commissions
12. Expansion of World Bank activities
13. Expansion of foreign aid programs

International Cooperation
14. Promotion of cooperative industrial R&D

SOURCE: Ancker-Johnson (1977).

by the National Science Foundation, and support for specific technology development (through R&D funding and/or procurement of new products) in furtherance of certain well-defined national projects, such as defense and space missions, and more recently the search for new sources of energy. Unlike many foreign governments, the U.S. government has rarely cooperated with the private sector on technology innovation in areas other than those in which the government itself was a customer. An obvious exception to this is agriculture.

In time of war, of course, much of the private sector's production has been for military purposes, and the federal government has very effectively assisted in the technological innovation of the private sector. The titanium-production program conducted by the U.S. Bureau of Mines beginning in 1943 (Baroch and others 1955, Baroch and Kaczmarek 1956) is an excellent example of cooperation between public and private sectors producing technological innovation, as was the titanium sheet rolling program established by the Department of Defense in the mid-1950s (NRC 1962).

BUREAU OF MINES

An exception to the government's peacetime policy of not directly assisting the private sector in technological innovation has been the programs of the Bureau of Mines. These programs have typically been justified by the need to improve the safety and health of miners and to ensure an adequate supply of strategic and critical raw materials. Since 1913, the mission of the Bureau of Mines has been:

> to conduct inquiries and scientific and technologic investigations concerning mining, and the preparation, treatment, and utilization of mineral substances with a view to improving health conditions, and increasing safety, efficiency, economic development, and conserving resources through the prevention of waste in the mining, quarrying, metallurgical and other mineral industries. [37 Stat. L. 681]

Although the main thrust of the Bureau's early programs was toward solving the safety and health problems involved in mining, from its beginning the Bureau undertook studies on the improvement of various mineral-related technologies. During World War II a great many of these efforts were concentrated on domestic mineral commodities that were of long-term importance to the United States. The Bureau's mineral-processing and metallurgical programs developed methods of upgrading some of the large domestic low-grade deposits of manganese and also investigated a number of processes for recovering aluminum from domestic nonbauxitic minerals. In the 1940s and 1950s, electrolytic processes for the production of manganese and chromium metal and metallothermic processes for production of titanium and zirconium were developed by the Bureau. These were promptly adopted by industry and are still used today in the United States and abroad. Much of the Bureau's metallurgical work in the early 1950s was aimed at developing economic methods of smelting and hydrometallurgical processing of complex ores to recover as many of their metals as possible and thus lower the U.S. dependency on imports. Mining research by the Bureau advanced safety and efficiency in the use of explosives, mine ventilation practices, and ground-support techniques. Bureau investigations of rock mechanics developed principles for design of safer and more efficient underground mines and open pits.

In many cases, Bureau projects have been conducted in cooperation with the private sector. Such cooperative programs ensured that the work was important to the interests of both the federal government and the private sector and greatly increased the probability that the technology would be transferred and put to early use. Examples of ventures involving the Bureau of Mines and some segments of the mineral industry show how successful such cooperation can be.

In searching for a flotation technique that would be widely applicable to diverse iron ore types, researchers at the Bureau of Mines observed and capitalized on the selective flocculation of iron oxides that occurred when starch was added to a dispersed ore pulp (see Frommer 1964). The product of the selective flocculation operation was a high-grade iron oxide concentrate. This technique was refined in cooperative studies with a Cleveland Cliffs Iron Company and then developed for commercial production in the 1970s, using their Tilden, Michigan, iron ore body (Sisselman 1975).

In the early 1970s, the gold-recovery operation of the Homestake Mining Company was enjoined by federal decree from using mercury in its milling plant at Lead, South Dakota, because of downstream pollution. Homestake's difficulties provided an opportunity for the Bureau of Mines to test new concepts for improved gold extraction, gold loading, and carbon handling in a cyanide carbon-in-pulp system (Potter and Salisbury 1974). The new system optimized the separate leaching, loading, stripping, and carbon regeneration operations. Its performance was demonstrated by Homestake in a miniplant and then scaled up to a successful commercial carbon-in-pulp plant meeting pollution regulations within two and one-half years after issuance of the federal decree (Hall 1974). In another application of Bureau of Mines technology for gold recovery, the Cortez Gold Mines at Cortez, Nevada, are heap-leaching low-grade ore with cyanide solution and then loading the gold on activated carbon in a countercurrent expanded-bed system (Duncan 1974).

A cooperative program initiated during the 1960s in the Coeur d'Alene mining district of northern Idaho was concerned with the rock bursts that occur in the deep mines there. Systems were developed for detecting and locating areas of stress accumulation in the rock surrounding the mine openings. Sensors and instruments now are routinely installed in several mines of the district to warn of an imminent violent failure of a wall or roof. The warning permits withdrawal of workers to a safe location or de-stressing by use of explosives.

Cooperative Bureau of Mines programs in progress include: alumina recovery from nonbauxitic resources, with a consortium of aluminum companies; hydrometallurgical processing of lead and zinc concentrates, with a group of domestic smelting firms; and tungsten recovery from Searles Lake brine, with Kerr-McGee Corporation.

NATIONAL SCIENCE FOUNDATION

While the main mission of the NSF has been the support of basic research, largely through the funding of the academic community, recently the Foundation has become involved in a series of experimental programs designed to foster technological innovation in the private sector.

According to J.T. Sanderson, Assistant Director of the National Science Foundation Directorate of Engineering and Applied Science (personal communication 1979), the goal of the National Science Foundation's government/industry programs is to find a balance between meeting social and economic needs and to determine a proper scale of governmental involvement and regulation. Programs involving government interaction with industry have been devised using universities as intermediaries. NSF aims to support good university research in engineering and other disciplines and combine it into packages that address industrial problems. The key to this process is the development of "generic technology," which no single company might be expected to finance because it alone could not capture the benefits of the innovation. Several of these projects illustrate the range of approaches being taken.

Manufacturing

Having determined that manufacturing makes up 30 percent of the GNP and that three-quarters of manufacturing is batch manufacturing, the National Science Foundation devised a project to attempt to reduce costs in batch manufacturing. The assembly of small electric motors was chosen as a sample industry, and a project was set up whereby the Westinghouse Electric Company, working in cooperation with seven universities, is attempting to reduce assembly costs through new technology. Westinghouse provides one-quarter of the required funds for the project, and NSF, through the participating universities, provides the remainder. It is hoped that this research method can be adapted to other industries and other commodities.

Low-Technology Industry

In an attempt to determine the efficacy of government intervention through the infusion of technology into a low-technology industry, the National Science Foundation has aided in the establishment of the Furniture Institute at the University of North Carolina. The Furniture Institute program is jointly funded by the National Science Foundation and the Southern Furniture Institute, an industry association. Industry contributes approximately two-thirds of the costs of the projects. The Furniture Institute has developed several process and product innovations, which have been licensed to industry for commercialization. Unfortunately, the Furniture Institute has not been able to stand alone in spite of several years of government support, presumably because of the fragmented nature of the industry.

Polymer Technology

Under its Experimental Research and Development Incentives Program, the National Science Foundation conceived the Polymer Processing Institute as an experiment to test the concept of creating long-range R&D incentives for a fragmented industry by establishing an <u>industrially</u> <u>sponsored</u> central R&D program at the Massachusetts Institute of Technology. The program, known as the MIT-Industry Polymer Processing Program, also tests whether academic institutions and industrial firms can effectively cooperate in solving research problems without jeopardizing the integrity of either party and whether the academic environment can be conducive to industrially relevant R&D work.

The program was initiated by a grant of $100,000 from NSF in 1973 to set up organizational relations, rules for patent rights and protection of confidential information, and criteria for evaluating its accomplishments. Later in the same year, NSF gave the program a grant of $370,000 to be spent over the next five years, after which the program would continue only with support from industry members and MIT.

At the end of the five-year period, the program's annual operating budget had risen to over $500,000 and was completely supported by its twelve industrial participants, with the majority of the funding coming from the three largest industrial partners. By that time, the program had been granted four foreign and three U.S. patents and had seven more under consideration.

The NSF program shows that the primary goal of fostering technological innovation can be approached through a number of mechanisms, each tailored to the combination of industrial, university, and governmental capabilities deemed most appropriate. The success of each mechanism will probably have to be judged in a different way, depending on the characteristics of the technology and the industrial units involved. The diversity of the mineral industries and the number of RD&D problems that can be anticipated suggest strongly that whatever "system" is set up to deal with them should, like the NSF program, accommodate a wide variety of institutional arrangements and should be flexible in management and funding.

5. ROLE OF THE PRIVATE SECTOR

Max Lerner (1957), in America as a Civilization, says, "Except in a climate of innovation, the American experiment would have been impossible; conversely, it was in the intensely innovating social climate of America that invention was bound to flourish." In our system the private sector not only has a role but it has a fundamental responsibility for the provision of goods and services required for our society to function. This is the social climate in which America has prospered technologically. While the private sector's technological achievements may have been overshadowed in recent years by government defense and space achievements, in which the government acted as the senior and directing partner, it is private industry which produces goods and services in response to general market demands, and it is industry in which technological innovation must take place if it is to yield benefits to the consumer.

When government intervention is prescribed, the challenge is to conduct that intervention in such a way that the private sector can fulfill its responsibility and thus gain by the assistance of government rather than be hindered by government. As the MIT study for the Office of Technology Assessment showed (OTA 1978), intense pressure by the government on the private sector for rapid change can be counterproductive; it may give the private sector no other alternative than to patch up existing technology rather than risk the failure and nonapproval of a radical innovation. Moreover, little innovation can be expected when government, or a government contractor, studies or develops a technology without the direct involvement of a unit of the private sector capable of picking up that information and transforming it into a commercial venture. As has been noted repeatedly, there is more to technological innovation than R&D.

Wartime successes of technical development led American industry in the post-World War II years to place new hopes on the use of R&D and technological development as a means of economic growth and corporate prosperity. Much of the economic growth and the prosperity of the 1950s and 1960s in the United States has been attributed to R&D. The rate of growth of total expenditures for R&D in industry was relatively constant for the twenty years preceding the recession of 1970-1971.

But the popular post-World War II belief of the 1950s that new knowledge--the result of pure scientific research--would automatically lead to technological innovation (see Figure 2.1) gave way in the 1960s and 1970s to the recognition that prior existence of a need coupled with a planned and concentrated problem-solving activity are key ingredients to economic growth through the process of technological innovation (see Figure 2.2). Businessmen who had looked at R&D operations in isolation and questioned whether their investment in R&D had produced an adequate return began to recognize that successful technological innovation requires a sequence of efforts of which the research laboratory is but one member of the sequence. Of special importance to the mineral industries is the identification and assessment of national R&D needs for mineral commodities, a task that could be effectively carried out through the federal Bureau of Mines with the assistance of the mineral industries.

In the United States, R&D is the prevalent method of solving problems by individual companies and generating new ideas for the company. The 1977 edition of "Industrial Research Laboratories of the United States" (Jacques Cattell Press) lists 10,028 R&D facilities belonging to 6,947 organizations engaged in fundamental and applied research. Most of these facilities are owned and operated by industrial firms, and range widely in size and the nature of the work performed; some foundation-supported and cooperatively supported units are also included, as are university laboratories having research facilities separate from university control.

RESEARCH ASSOCIATIONS

Industrial research associations have been established within some industries in the United States (Table 5.1). Unlike the British government, the U.S. government offers no categorical support to these associations. What federal funds are obtained by U.S. industrial research associations are in the form of contracts awarded to produce specified results. Like their British counterparts, however, American research associations are financed largely by the subscriptions of their member companies.

Research Associations of Regulated Utility Industries

Regulated industries present special cases because their profits are both controlled and ensured, and the costs allowable for rate-setting purposes are controlled. Two industrial research associations run by regulated utilities are examined below.

Electric Power Research Institute

The Electric Power Research Institute (EPRI) was founded in 1972 by the major sectors of the nation's utility industry to develop and

TABLE 5.1 Industrial Research Associations in the United States, 1975

Name of research association	Date formed
American Concrete Institute	1905
American Iron and Steel Institute	1908
American Petroleum Institute	1919
ANPA Research Center (newspapers)	1947
Association of American Railroads Research and Test Department	1950
Bituminous Coal Research Inc.	1936
Edward Ortin, Jr., Ceramic Foundation (kiln-fired ceramics)	1932
Electric Power Research Association	1972
Gemological Institute of America	1931
Gidley Research Institute (industrial rubber)	1943
Graphic Arts Technical Foundation	1924
Hardwood Plywood Manufactureres Association	1921
Hertz Foundation (wood and wood paper products)	1939
Illuminating Engineering Research Institute	1944
Institute of Textile Technology	1944
International Copper Research Association	1960
International Fabricare Institute (Formed from American Institute of Laundering, founded in 1874, and National Institute of Dry Cleaning, founded in 1907)	1972
International Lead-Zinc Research Organization	1958
NAHB Research Foundation (home builders)	1965
National Canners Association Research Foundation	1961
Portland Cement Association Laboratories	1916
Quality Bakers of America Cooperative Laboratories	1924
Sulphur Institute	1961
Smelter Control Research Association	1971

TABLE 5.1 (Continued)

Name of research association	Date formed
Tile Council of America Research Center	
Asphalt Institute	1919
Institute of Paper Chemistry	1929
Textile Research Institute	1930

SOURCE: Gale Research Company (1975)

administer a coordinated national electric power R&D program. Through selection, funding, and management of research projects conducted by contracting organizations, EPRI promotes the development of new and improved technologies to help the utility industry meet electric energy needs in environmentally acceptable ways. The primary areas of EPRI's research are fossil-fuel systems, advanced technology systems, nuclear power, electrical systems, environmental assessment, and energy analysis.

EPRI funding comes entirely from voluntary contributions from approximately 500 member utilities across the country, representing three-fourths of the nation's electric service. These utilities are both investor-owned and public-owned (through municipal systems and the Rural Electrification Administration). The Tennessee Valley Authority (an agency of the federal government) is the largest single contributor to the program. In 1979, member utilities contributed the equivalent of 0.193 mill per kilowatt-hour of their consumer sales.

Since 1972, more than 1,500 research projects have been initiated, and more than 1,200 reports have been published on EPRI research projects. There are currently approximately 1,300 active R&D projects under EPRI management. The EPRI funding commitment for the lifetimes of these projects totals almost one billion dollars. Cofunding and cost sharing by contractors and other organizations nearly double that figure.

The 1979 R&D budget for EPRI was $202 million. The proposed distribution of funds into R&D programs for the period 1979-1983 is:

		Percent
Fossil Fuel and Advanced Systems		43.6
Fossil fuel power plants	13.6	
Advanced fossil power systems	16.4	
New energy resources	5.1	
Energy management and utilization	8.5	
Nuclear Power		27.3
Water reactors systems technology	7.9	
Reliability, availability, and economics	7.1	
Fuels, waste, and environment	5.3	
Developing applications and technology	7.0	
Electrical Systems		16.7
Transmission	9.7	
Power systems	7.0	
Energy Analysis and Environment		12.4
Energy analyses	3.7	
Environmental assessment	8.7	

EPRI's research management functions are carried out by four technical divisions, which report to the president of the institute. The board of directors sets overall EPRI policies and direction. The Washington Office, the Administrative Division, and the Communications Division provide services to the various technical groups within the institute. The planning staff, which reports to the president, coordinates EPRI R&D planning and assists in determining funding emphasis.

A vital part of EPRI's organization is the advisory structure. EPRI's advisory council has the responsibility for maintaining communications between the general public and the board of directors. This council includes representatives of government, business, education, labor, and environmental and consumer groups. The Research Advisory Committee is an industry group that counsels the board of directors and EPRI's president. Each technical division is counseled by a division advisory committee made up of utility industry representatives. The Communications Division is similarly advised by an industry committee.

The EPRI management and staff plan, manage, and analyze projects of the institute. All other aspects are contracted out to universities, member utilities, R&D and engineering firms, equipment manufacturers, and consultants. The technical information generated is available to member utilities and the public at large through various communications from EPRI. EPRI does not emphasize demonstration projects; utilization of the technology developed by EPRI is the responsibility of the individual utility companies.

Gas Research Institute

The Gas Research Institute (GRI) was founded in 1976 as an independent, not-for-profit, scientific organization for the purpose of planning and implementing a comprehensive R&D program for the benefit of the gas consumer. It has roots in the American Gas Association and the Institute of Natural Gas Associations of America. Its members are interstate pipeline companies, distribution and intrastate pipeline companies, and municipal utilities; several Japanese companies are associate members. In 1979, its budget was $110 million.

GRI conducts no in-house R&D. Like EPRI, all of its projects are contracted to major not-for-profit research institutes, technical consulting firms, universities, energy companies, and equipment manufacturers. Many of these projects are funded cooperatively with the performer or with various government agencies. GRI's 1979 budget, for example, comprised $40 million raised, with the approval of the Federal Energy Regulatory Commission (FERC), by a charge to consumers of 3.5 mills per thousand cubic feet of gas sold; $65 million in cooperative funding from government agencies; and $5 million from manufacturers. The distribution of funds among R&D program areas for 1979 was:

	Percent
Supply	54.9
Conservation	26.6
Planning and economic analysis	8.4
Basic research	5.4
Environment and safety	4.7

GRI's progress was stimulated in June 1977 when the former Federal Power Commission (FPC) adopted a rule change allowing advance approval of R&D programs developed, under a set of carefully drawn guidelines, by organizations that derive financial support from companies under FPC jurisdiction. These guidelines have since been promulgated by FPC's successor, the Federal Energy Regulatory Commission (FERC). In accordance with the requirements of the FERC guidelines, GRI submits a five-year R&D plan yearly to FERC for approval, providing evidence that:

- the R&D objectives have been clearly established;
- the plan evolves from these objectives and takes into account the viewpoints of scientific, engineering, economic, consumer, and environmental interests;
- an effective mechanism is used for coordinating the R&D plan with other relevant efforts of national scope;
- the program is well conceived and has a reasonable chance of benefiting the ratepayer in a reasonable period of time.

Like EPRI, GRI has a project-oriented organization reporting to a president. The board of directors is composed of representatives from each of the three major industry areas--interstate pipeline companies, distribution companies, and municipal utilities. To fulfill the requirements of the FERC, GRI has four advisory groups:

- <u>The Advisory Council</u>, a diverse group of eminent people from outside the gas industry, representing scientific, engineering, economic, consumer, regulatory, labor, industrial, and environmental viewpoints, and helping to ensure that the GRI program serves the public interest.
- <u>The Research Coordination Panel</u>, composed of leaders in the R&D community outside the gas industry who help to coordinate GRI's programs with the R&D efforts of the federal government and private organizations.
- <u>The Industry Technical Advisory Committee</u>, composed of technical experts from within the gas industry, who advise the GRI Board and staff of gas technology requirements and the practicability of anticipated results in gas-industry operations.
- <u>The Muncipal Gas System Advisory Committee</u>, representatives from municipal gas systems who advise on the specialized needs of the municipal gas customer.

Research Associations of Nonregulated Industries

Private domestic industries that form research associations generally do not carry out production-oriented research, presumably to avoid problems of antitrust law violations. Their research is generally focused on product- and market-oriented activities or industrial safety and health. Two exceptions are the American Iron and Steel Institute and the Smelter Control Research Association.

American Iron and Steel Institute

The American Iron and Steel Institute (AISI) is primarily a cooperative information organization of the U.S. steel industry. But while it has no laboratory facilities itself, it does support production-oriented research through the funding of projects at universities. It is currently sponsoring 45 university projects on subjects including mining, mineral beneficiation, chemical additives to grinding, processes for de-sliming slurries, and filtration of slurries. Representatives of the member companies of AISI meet each year to establish the research priorities and the subject matter of the university proposals. Because of member company participation in the selection of research priorities, the AISI research program reflects to some degree the technological needs of the member companies and of the industry as a whole. All work is nonproprietary and is publishable by the universities. The individual companies rely on their in-house technical facilities to utilize AISI-generated research results and to carry the findings of such research into technology suitable for their own use.

Smelter Control Research Association

The Smelter Control Research Association (SCRA) was organized in 1971 for the purpose of performing cooperative studies, feasibility studies, and demonstration projects on the treatment of reverberatory furnace waste gas streams. Its membership consists of the major domestic copper producers and its operating expenses are derived from its membership on the basis of the annual copper production of each member. No federal funds are involved in the operation of SCRA. The association has a board of directors elected by the members, a technical committee, and a president appointed by the board.

Projects originate with the technical committee and are approved by the board. Typically, the technical committee designs the approach to the project, sees to the project's execution, and evaluates the results. Projects range from paper studies to large-scale demonstrations and are performed by contractors. The annual budget for SCRA depends upon the size of the projects in progress at the time; it has ranged from $300,000 for study projects to over $1,000,000 for demonstration projects. The results of all work are published.

Smelter Environmental Research Association

The Smelter Environmental Research Association (SERA) is a cooperative effort in industrial hygiene and occupational health and safety located at the University of Michigan at Ann Arbor. Its members are the major domestic smelter operators, which include the copper, lead, and zinc industries. It has a board of directors, a scientific advisory committee, and a president. Its projects are contracted out to university investigators or to research firms. SERA typically has approximately ten projects in operation at one time, with a total budget between $200,000 and $300,000. Like SCRA, SERA receives no federal assistance, and all research findings are made public.

Chemical Industry Institute of Toxicology

In the chemical industry, generic research on the toxicity of commodity chemicals is conducted by the Chemical Industry Institute of Toxicology. Policy is decided by a board of directors elected from the member companies. Costs of the research are paid by the member companies. Companies are divided into three categories according to their sales, and fees are assessed at three corresponding levels. A priority committee selected from the members determines the order in which compounds are tested. Research results are published and made available to the public.

Aluminum Association

The Aluminum Association, like AISI, exists primarily to provide information concerning aluminum and its products. The association does not have a research budget, per se, but it supports R&D through technical committees. Each committee asks for line items in its budget when R&D is required. Most of the research sponsored by the Aluminum Association deals with operations, products, and marketing. An example of a project relating to operations involves safety aspects of water and molten aluminum. Past attempts by the Aluminum Association to do process research have failed because of competitiveness of major companies within the association.

International Copper Research Association and International Lead and Zinc Research Organization

The companies involved in the primary production of base metals (copper, lead, and zinc) have, for a number of years, maintained cooperative R&D organizations working in the areas of product development and new applications for their products. As the names imply, membership is made up of both domestic and foreign companies. The market for basic metal commodities has traditionally behaved cyclically. The main purpose of these research associations is to attempt to dampen this cyclical behavior by creating new markets for the base metals and to preserve the markets already established. In addition, these associations add to the world's scientific knowledge about these metals. Research is performed under contract with universities and contract research laboratories in the United States as well as abroad.

In the same industries, trade promotion organizations, such as the Copper Development Association, the Lead Industries Association, and the Zinc Institute, exist to enhance the marketing of the products of their members. All these organizations operate under boards of directors representing member companies and are financed by dues collected from members on the basis of production.

Bituminous Coal Research, Inc.

The bituminous coal industry has sponsored a research organization, Bituminous Coal Research, Inc. (BCR), since 1934. In 1960, BCR became affiliated with the National Coal Association (NCA), and BCR receives its principal continuing support from the bituminous coal industry through NCA. It sponsors and conducts research to improve technologies in mining, coal handling, preparation, beneficiation, safety, and health, and the use of coal. In cooperation with NCA, BCR addresses coal-related problems in the laboratory and in the field, as well as through communication with agencies that promulgate regulations affecting the production and use of coal.

BCR operates under a board of directors and an executive committee consisting of representatives from NCA-member companies as well as staff members of NCA. The officers are staff members of BCR or NCA. BCR has two divisions: administration and research. The Research Division has five departments: Chemical Research and Testing, Mining Research, Utilization Research, Environmental Research, and Petrographic Research. BCR's personnel complement at the end of 1979 totaled 90.

As a focal point for research in the bituminous coal industry, BCR forms technical committees composed of industry specialists to coordinate the research activities of the industry, to provide liaison with equipment manufacturers and contractors, and to communicate with federal agencies on their respective subjects. In 1979 active committees were: the Mining Production Research Committee, the Respirable Dust and Noise Committee, the Cabs and Canopies Committee, the Mine Monitoring and Communications Committee, and the Longwall Mining Committee.

In addition to the research sponsored and financially supported by the coal industry through NCA, the BCR laboratory does contract research for federal agencies, including the Department of Energy, the Bureau of Mines, and the Environmental Protection Agency, and for the Commonwealth of Pennsylvania, as well as for noncoal industry groups. In 1979 the operating budget was approximately $3 million. Coal-industry sponsored projects provided about 20 percent of the operating funds and the remainder was provided by federal government contracts. BCR in recent years has not sponsored research projects at outside firms or universities except through subcontract under federal government projects.

The research areas at BCR are prescribed by the R&D policy statement of the board of directors. Research planning is generally a joint effort by the BCR staff and the technical committees. Projects and budgets are approved annually by the board. The specific project objectives and implementation plans are developed by BCR personnel usually with advice and assistance from the technical committees.

Research results are communicated to the BCR member companies through published reports. Significant achievements are generally the subject of special publications and "technology transfer seminars." The technical committees often participate in project review sessions and through these reviews become acquainted with the progress and potential application of new or improved technologies.

UNIVERSITIES

The land-grant colleges established by the Morrill Act in 1862 and the agricultural experiment stations set up in conjunction with land-grant colleges by the Hatch Act in 1887 have three charges: teaching, research, and public service. Beginning with agricultural research, university research has grown into a "big business" in the United States, with a total budget of approximately $5 billion in 1979, the vast majority of which comes from the federal government. Collectively, the universities of the United States represent the largest pool of scientific expertise in the world. Recent concern for the decrease in U.S. technological innovation has reopened interest in bringing the university community into closer interaction with the industrial innovative process. Because the major share of basic science development occurs in universities, while technological development is lodged primarily in industry, there are strong arguments for coupling the two sectors, although the coupling is not always easy or simple. Fusfeld (1980) describes the situation as follows: "University-industry relations in science and technology have long been characterized by curious mixtures of respect and condescension, of affection and irritation, of strong mutual interactions and barriers, planned and philosophical."

Colleges and universities, particularly land-grant colleges, were once very attentive to industry needs, but after World War II this attentiveness diminished,. Smith and Karlesky (1977) have identified three factors underlying this decline:

- the separation of academic research from recognized industrial needs as a result of the increasing role of the federal government in science and technology;
- the decreased interest among university graduates in industrial research careers--with the availability of federal funds for academic research and education, more and more graduates eschewed industrial careers for careers in academic research; and
- industry's decreasing role in basic research. The industrial share of basic research spending declined steadily between 1955 and 1972, and the proportion of the in-house R&D budget allocated to basic research decreased dramatically after 1966. Since the key to cooperative interaction between universities and industry was scientist-to-scientist contact on matters of common interest, the general decline in industrially performed basic research decreased such contacts and impeded university-industry relations.

In commenting on federal funding of university research from 1950 to 1970 Fusfeld (1980) describes the change in relations in these words:

> . . . But the bridge between university and industry, although neither completely broken nor abandoned, fell into disuse. Research subjects evolved from governmental goals and funding, and career objectives of graduates were geared to the glamour and growth of space, nucleonics, and the new age of materials science. While industrial research became stronger internally, the university research community leaned toward its new and generous patron.

Courtland D. Perkins, president of the National Academy of Engineering, has attributed many of the problems in today's graduate engineering programs to the continuing divergence between industrial R&D and the programs remaining in our engineering graduate schools. He asks, "If modern high-technology industry questions our graduate programs to the extent that they hire our best undergraduates and see to their continuing education and motivation themselves, what does this mean to engineering education programs in the long run?" (Perkins 1980). He recommends that we revitalize the interconnection between industry and university programs.

Prager and Omenn (1980) observe that a return to close university-industry involvement may today be in the best interests of both sectors. The university community shows a growing interest in solving national problems and a renewed appreciation for the role of industry in such problem solving. Competition for federal research funds has dramatically increased as inflation has eroded the research dollar and university programs have proliferated. Government regulations related to scientific and financial accountability, human and animal experimentation, biohazards, and affirmative action have reduced the efficiency, flexibility, and independence of the academic scientist. Fusfeld (1980) notes the following: "The bridge with industry was rediscovered by universities around 1970, with the slowing of federal support, cutbacks in aerospace research, and narrowing of federal support following the Mansfield Amendment. Initial approaches were made by universities with overtones of 'with your money and our brains'--not an endearing note, and surely not the best one on which to begin a relationship. But through the 1970's a maturing sense of mutual benefits and interdependence has emerged."

University administration and faculty are turning to industry as a source of research support, as a potential employer for graduates with advanced degrees, as a source of part-time faculty, and as a focus for continuing education programs.

Industry's incentives for university cooperation are equally compelling. American companies are engaged in stiff competition at home and growing challenges abroad. New science-based technology is needed to meet not only these challenges but also those of environmental, health, safety, and product-efficiency regulations imposed by society.

But in spite of the potential interest of both sectors in cooperation, there are a number of barriers to be overcome (Prager and Omenn 1980). Academic institutions are in the business of education and training. University research is thus necessarily oriented toward education and basic research. It is seldom directed at new commercial products or processes; the emphasis is basic science and engineering rather than development and commercialization. The time frame for academic research is long. Freedom of communication and publication is at the heart of the academic research process, and intellectual independence is paramount. Finally, a university's most important considerations are the number and quality of its students and its research productivity; its responsibility is to the public.

Industry's fundamental interests are financial viability and profits; the goal of its research is new, improved products, processes, and services. Industry's responsibility is to its stockholders. Some academicians appear to disdain the profit orientation and distrust the motives of industry. Some seem to believe that industrial researchers and the quality of their research are inferior and that university-industry interaction means industry direction of university research, applied research only, lower standards, no publications, proprietary work only, and no real interaction. On the other hand, university research is viewed by some individuals in industry as being indifferent to applicability and relying too heavily on a cumbersome publication process.

The challenge for the mineral industries and universities alike is to overcome these barriers and create situations in which the resources of both sectors can be used to mutual advantage. The National Science Foundation-initiated consortia programs discussed earlier show that the industry/academia barriers can be overcome. Moreover, of the research associations listed in Table 5.1, at least three have cooperative programs with, and are located close to, university campuses: the Asphalt Institute is associated with the University of Maryland, the Institute of Paper Chemistry with Lawrence University, and the Textile Research Institute with Princeton University. These associations employ faculty members and graduate students, sponsor university research, and cooperate with the university in graduate training for degree programs.

Mining Schools and Colleges and the Mining and Mineral Resources Research Institute Program

In the United States as well as elsewhere in the world, the educational and academic research needs of the mineral industries are met largely by schools and colleges of mines. These, like the agricultural colleges, are special purpose institutions whose main focus is mineral-resource exploration, development, and production. Schools and colleges of mines are an important component of the mineral resource effort of the nation and a vital national resource in themselves. The principal role of these mining-oriented educational institutions is to provide the expertise required to operate the nation's mineral industries, through undergraduate curricula, graduate curricula, and continuing education for professionals already in the industry. In addition, these schools apply science and technology to the solution of problems encountered by the mineral industries.

In 1969 the National Research Council published a study entitled Mineral Science and Technology: Needs, Challenges, and Opportunities (NRC 1969). The committee was concerned over the lack of coordination and support of mineral-resource research by federal and state governments as compared with the organization and funding of research on agricultural resources. The committee made a comprehensive list of recommendations directed to the federal government, the state governments, the mineral industries, the universities, and the professional societies. The committee proposed the establishment of a broad mineral-resource policy and management program in government with a strengthening of government-industry-university relations supporting the national mineral-resource objectives. Emphasis was placed on the role of the universities in the fulfillment of these objectives.

The recommendations of the 1969 National Research Council report ultimately led to the passage of Title III of PL 95-87, creating State Mining and Mineral Resources Research Institutes (MMRRI) at public colleges and universities in 31 states. This title authorizes the appropriation of federal funds to match state funds for institutional support up to $400,000 per institute per year and for the support of research at these institutes amounting to a maximum of $27 million per year. Fiscal Year 1980 was the third year of operation for the program. Unfortunately, Congress restricted the funding of the program to a total of $10 million per year, which amounted to $110,000 per year per institution for institutional support and $6.59 million to be spent for research and fellowship support of students for FY 1980. The Department of the Interior has not requested funding for this program in FY 1982.

The MMRRI program has reinvigorated a number of the mining schools and colleges and mineral-resource programs in other universities; the reduced level of funding, however, has limited the progress of these institutions toward their goal of achieving a meaningful role in the development of mining and mineral-resource technology and the early termination of the program will undoubtedly cause some of the weaker institutions to falter.

PROFESSIONAL SOCIETIES

Professional engineering and scientific societies also play an important role in technological change in the United States. Some of the largest related to the mineral industries are the American Institute of Mining, Metallurgical, and Petroleum Engineers, the American Institute of Chemical Engineers, and the American Chemical Society. These societies and the many smaller but important specialized societies act as catalysts--neither entering into the innovation process of the country nor undergoing change themselves as a result of it. They receive little financial support from either industry or government. Their main role is to disseminate technical information through publication of scientific journals, texts, and reference books and by sponsoring symposia, short courses, and seminars on subjects appropriate to their disciplines. Membership is on an individual, voluntary basis, and educational and professional experience requirements are strict.

In past years, the professional societies have responded rapidly to national needs for technological initiatives. Through increased programming, the societies have informed and educated scientists and engineers, briefed government officials on professional views and opinions, and provided industry leaders with a forum for interaction and communication with the professional community. In addition to reacting to new programs and opportunities, the professional societies have also played an important role by providing expert testimony to congressional committees and informing the public and society membership through society publications. Professional societies also interact closely with universities and their faculties, which include many members of the societies. There is a long history of cooperation between academia and the professional societies in program accreditation and development of academic facilities.

Thus, the professional societies influence all aspects of the technological innovation process, from manpower supply to public information on technical matters. It can be expected that the societies will continue to play a major role in technological innovation in the mineral industries.

6. ANALYSIS, CONCLUSIONS, AND RECOMMENDATIONS

ANALYSIS

Branscomb (1980) sets the stage for the Committee's analysis with these words:

> The quality of technology actually used in U.S. industrial production is best mirrored by looking at productivity figures. There the U.S. economy demonstrates a miserable performance overall, with a productivity growth rate that lags that of most of our foreign industrial competitors. Yet much of this poor performance is not a reflection on the technology of which our engineers are capable, and certainly not on our science. Instead, it reflects the failure of our society to give priority to savings and to capital formation, plus a great variety of social and political barriers to the replacement of antiquated plant facilities by more productive new ones.
>
> While there are no quantitative data that can be used to assess the comparative states of technology here and abroad, I am convinced that even where our industrial technology lags that of competition, our capability does not. American engineers are capable of accomplishing more than what is actually built and made in many of our factories. It is not that our technology is weak or lagging. It is that we are failing to push as rapidly ahead as we could as a nation.
>
> . . . the picture of American science and technology today is one of great strengths yet deep doubts, of strong foundations and timid commitment, of critical importance to the economy and uncertain political priority. If indeed our domestic and our foreign trade performance are poor, is lagging technology the symptom or the cause? And if technology lags, is this because the steam has gone out of our science? Or because of a failure of economic policy and industrial will?

> There is plenty of room for debate, but there is an obvious conclusion: whatever the cause and effect relation between scientific, technological, and industrial performance, our nation should commit itself to excellence in all three areas. No less a goal is worthy of us.

Innovation in the mineral industries is a complex process that starts with an advance in the understanding of the ore-forming process of nature, the identification of an industrial problem to be solved, or the recognition of a mineral-related societal need. The process usually continues with research and development programs resulting in new information, a new product possibility, or evidence of the effectiveness of a potentially useful process. It continues with further testing and evaluation, scale-up, market development, and, finally, investment in new plant and equipment. Innovation does not occur until a decision is made to commercialize the results of R&D and the new technology is made available in the form of an operating process or a new product. Successful innovation involving a process usually requires a continuing flow of capital and further market development. In the case of a product, innovation may be delayed until a new distribution system is developed. In the case of a process, innovation may be delayed until various permits are obtained, public hearings held, and fees paid. Innovation is a process that is not complete until the results of the decision to commercialize are in place and available to society.

In free economies the driving force behind innovation is the expectation of return on invested capital. Innovation is strongly influenced by the perceptions of executives in the mineral industries of costs, time required for commercialization, competitive risks, risks from uncontrollable factors, and estimates of future cash flow. These perceptions and estimates dominate the entire process including the funding and use of R&D. Innovation will not take place, however much R&D is performed or however unique its results, when the executives of the companies (and of the financial institutions upon whom they depend) anticipate high risks and inadequate return on investment. Technological innovation in the mineral industries depends on a vigorous R&D effort to identify opportunities for innovation, the ability of the industry to innovate, and the perceptions (real and otherwise) of the incentives for developing and using new technology. Any effort to increase the level of technological innovation must address how actions of government and the universities affect R&D. It must also take into account all of the direct and indirect interactions of industry and government on the succeeding steps of the innovation process.

Decline of the Domestic Mineral Industries

The General Accounting Office (1979) has documented the decline of the U.S. mineral industries, based upon a number of yardsticks--decreasing profitability, increased debt, reduced rate of growth, and in some sectors the actual closure of facilities. Decreased return on investment and reduced profitability have forced the mineral industries to trim R&D budgets, defer modernization, and in some cases terminate advanced development stage projects already under way. The ultimate result of this decline has been a lag in innovation, and lagging innovation brings about further decline.

In the last 25 years the position of the United States has changed from near self-sufficiency in many important minerals to import dependence for over 50 percent of the supplies of 20 basic minerals essential to the economy. Such dependence on imports brings concomitant strategic and economic vulnerability. In recent years shortages of critical materials and volatility in their price have had subtle (and to a considerable degree inflationary) impacts on virtually all manufacturing. The severity of these impacts is only beginning to be recognized. It is appropriate to examine the causes of the decline in the mineral industries and ways technological innovation might be effected in order to re-establish the vitality of these industries.

As previously discussed, there are four general causes of the decline in domestic mineral industries:

(1) Increased risks
(2) Decreased levels of R&D investment
(3) Not fully recognized characteristics of many of the industries
(4) The deteriorating investment climate for capital-intensive industries in the United States

Increasing risks associated with investments in new technologies for domestic operations stem from (a) competition from overseas mineral operations that have a favorable market position as a result of foreign government ownership or subsidization, (b) the reduced influence of market forces in foreign countries as a result of government ownership or subsidization of operations, and (c) the possibility that ore deposits of higher grade than those in the United States will be discovered in foreign countries, thus putting domestic operations at a disadvantage in the mineral market.

In the last 25 years the United States mineral companies and the federal government have made relatively low levels of investment in research and development. A Battelle report to NSF (Battelle-Columbus Laboratories 1979) on the adequacy of the current levels of research and development for the nonfuel mineral industries pointed out the low level of investment in R&D by industry as well as by the Bureau of Mines, the National Science Foundation, and other government agencies. Both industry and government have made inadequate investment in what has been called the "front end" of the mineral production system, that is, exploration, mine development and operation, and mineral processing.

The mineral industries are rather unusual among capital-intensive industries. The effects of various parts of the environment in which the mineral industries must operate may not differ in kind but do differ substantially in degree from other industries. Some of the characteristics that set the mineral industries apart are production of a commodity-type product (i.e., a raw material), unusual levels of technical and business risk, and the significant competitive differences in the quality and location of ore bodies. Also influencing the level of innovation in the mineral industries has been the deteriorating investment climate for domestic capital-intensive industries. Part of the deterioration stems from a shortage of capital caused by inadequate depreciation allowances. Part is due to the difficulties in obtaining long-term energy commitments at acceptable prices, and part can be traced to the capital requirements for meeting regulatory environmental, safety, and health standards.

One of the less widely recognized characteristics of the mineral industries is the long lead time required to bring a deposit into production, often as much as 10 years or more. Many of the present working mines of the world will be exhausted by the year 2000. If United States is to overcome the strategic and economic vulnerability of present import dependence, a major effort must be made now for useful innovations to be effective in the first part of the 21st century.

The future of the mineral industries in the United States can be bright. While the outlook for future discovery of critical materials such as chromium, cobalt, and tungsten may appear to be dim, the possibilities are good for increasing the vitality of the domestic minerals industries in supplying minerals for which the resources of this country promise full or partial self-sufficiency. A revitalization of these industries with concomitant benefits to the U.S. economy and society is essential. One of the keys to the revitalization of the industry is technological innovation.

Opportunities for Technological Innovation

There are many opportunities for research that could lead to innovation. Battelle's report to NSF (Battelle-Columbus Laboratories 1979), Assessing the Adequacy of Research and Development, pointed out specific, attractive avenues of research in exploration, in mine development and operation, in mineral processing, and in basic materials processing. To fulfill the promise of such technological opportunities, however, requires actions by all institutions directly or indirectly affecting the innovation process in the mineral industries. Such institutions include companies in the mineral industries, a number of important agencies of the federal government, universities and other research centers, and professional societies. Only with concerted effort on the part of all of these institutions can real progress be made toward the application of technology in the reduction of import dependence and its consequences, stabilizing materials supplies and prices for domestic manufacturing industries, and increasing domestic employment in mineral processing.

No Single Approach

The diversity and changing character of the mineral industries preclude the possibility of a single approach for improving technological innovation in all sectors. The three classes of mineral industries--ore-deposit centered, process-centered, and market-centered--differ in their mode of operation and underlying strategies. Efforts to stimulate industrial innovation must recognize these differences. It is clear to the Committee that improvement in the status of the U.S. mineral industries will require, minimally: (1) the establishment of mechanisms to develop new technology essential to the innovation process, and (2) sufficient incentives to motivate corporate managements to incorporate innovation as part of their business strategy.

To establish mechanisms for innovation, the private sector must provide inducements to attract outstanding researchers and process engineers who can bring fresh insights to new technology. This will certainly involve working closely with institutions having mineral engineering programs. Additionally, mineral-resource company managers have the responsibility to examine their own business operations and strategies to uncover internal barriers to change and then to take vigorous steps to overcome them. Company executives must take the responsibility for organizing the institutional mechanisms to develop new technology and for controlling choices of projects to be undertaken. The RD&D stage of the technological innovation process offers an excellent opportunity for establishing a partnership between industry and government wherein both share in the risks, costs, and conduct of certain RD&D projects under some suitable institutional framework.

The federal government has primary responsibility for improving the atmosphere for technological innovation by reviewing and adjusting policies and regulations that currently discourage it. Based on the domestic policy review of industrial innovation during 1979 and 1980, some agencies of the federal government are actively seeking ways to improve the atmosphere for innovation by reviewing and adjusting policies and regulations that would encourage innovation. Smith (1981) describes recent approaches used by the Environmental Protection Agency that indicate the improvement in the regulatory attitude and that to some degree facilitate and encourage the development and adoption of new technology. Continuing effort will necessarily involve the Mine Safety and Health Agency and the Office of Surface Mining Reclamation and Enforcement, and the Department of Justice for antitrust matters, the Department of Commerce for patent matters, and the Environmental Protection Agency and Occupational Safety and Health Administration.

Cooperation with industry on technology development, however, clearly falls to one agency, the Bureau of Mines, of the Department of the Interior. This federal agency has historically interacted with the mineral industries and has demonstrated its ability to work with them in developing and installing new technology.

In its deliberations, the Committee continually sought for an ideal organization and plan to integrate better the efforts to stimulate technological innovation by government and industry. We had hoped that one or more of the existing organizational arrangements would provide a satisfactory pattern on which to build. But each of the examples currently used in the United States and elsewhere appeared to be only partly responsive to problems of innovation in the U.S. mineral industries. Most approaches seem to have fallen short of the mark for two reasons: (1) the removal of disincentives to technological innovation was not addressed, and (2) the transfer of technology from R&D to implementation was left to chance.

In the examples studied the gap was too great between the organization performing the R&D and the organizations expected to assess and use the results, and the constraints that discourage acceptance of new technology either were not recognized or not dealt with. The approach followed by the Electric Power Research Institute (EPRI), for example, does not appear to be suitable to the mineral industries. While EPRI is in a good position for promoting the development of innovative technologies, and operating utilities provide guidance through membership on management and technical committees, there is little force within EPRI to bring the technologies to fruition through installation and operation by the utilities. Further, the institute cannot lessen or eliminate the disincentives to technological innovation that may influence the industry or the individual utility.

Industrial Research Consortia

The Committee believes that industrial research consortia provide an especially suitable mechanism for encouraging technological innovation in the mineral industries. Although the Committee prefers not the recommend a specific organizational format for the performance of the RD&D stages of the innovation process in the mineral industries, certain principles of organization and operation are recognized as applicable to the diverse interests of these industries. First, the investments necessary to develop new technology will clearly require cooperation of groups of companies within each of the mineral industries. Cooperation of the federal government will also be necessary in some types of projects, particularly large-scale demonstrations. To encourage such cooperation, some form of industrial research consortium would seem to be required for logical groupings within an industry. Such consortia now exist in several of the mineral industries for product research and promotional activities; consortia for mining and process technology are also needed. The nature and role of industrial research consortia are discussed in detail by Wolek (1977).

To the Committee's mind, industrial research consortia would have a number of positive aspects:

- The technology would be developed by an organization close to its users, thus minimizing the transfer problem.

- The cost of developing technology for common use would be shared and borne by the intended users.

- Member companies would control the program and monitor closely the progress and technical findings but would receive no exclusive proprietary benefits.

- Member companies would be expected to develop proprietary technology in their own R&D programs, which might be based on, but not part of, technology developed by an industrial research consortium.

- Each industrial research consortium would closely coordinate its activities with degree-granting programs at host or neighboring universities, thus tapping this resource for its talent while assisting in the training of new mineral scientists and engineers.

- Industrial contributions to technology development having a national interest such as environmental protection, safety, and health could be effectively "levered" by federal funding obtained through cooperative agreements and contracts.

The Committee does not suggest from which quarter the impetus should come to organize the first and successive industrial research consortia as here proposed for the mineral industries. History shows that the initiative in forming a new scientific and technological entity--whether a society, a company, an institute, or even a government agency--has been taken by an individual or small group dedicated to a particular purpose and willing to devote the time and energy necessary to assemble interested participants and organize the proper institutional arrangement. In the case of an industrial research consortium, it could be an office of a concerned segment of industry, a university faculty member, or a government official who felt strongly about the problems and issues discussed in this report. Such an individual might chose to work under the aegis of a technical society, an industry association, a government agency, or the National Research Council in being the focal point and "sparkplug" for the venture.

CONCLUSIONS

The question of how the status of technical development in the domestic mineral industries can be improved is complex. The process by which technical development comes about--technological innovation--is complex in itself. The effectiveness of the process in any industry is influenced by factors internal to the industry and factors involving government, generic technologies, markets, and competition. Solving the problem of technological innovation in the domestic mineral industries must have two main initiatives if it is to be successful:

(1) incentives must be structured to encourage companies to invest in the innovation process, and (2) science and engineering talents must be focused on the RD&D phase of innovation. The latter requirement is particularly important when the cost of development and demonstration of a new process is so great that no one company can afford the necessary investment.

Both government and industry should place increased emphasis on the role of technology in improving domestic mineral supplies and processing. The emphasis should include support of educational programs in mineral science and engineering and the training of professionals to strengthen awareness of technology among corporate management. The mineral industries are highly dependent upon technology but their current development and use of new technology lags behind that of other countries. An important factor in improving this situation will be technically proficient and aggressive people at all levels of corporate and operations management. Labor skills also must be upgraded to make possible the operation of more complex technologies.

Mineral market analyses and other minerals information published by the federal and state governments, while useful for many purposes, are generally considered to be inadequate for evaluating the potential of new mineral technologies. Evaluation is particularly important during the early stages of development of any substantial departure from conventional technology, when sound information for government and industry must precede policy and action.

The Committee is also convinced that the mineral industries must engage in collaborative research on problems generic to them and related industries. Discussions between Committee members and mining company executives revealed agreement that such activities are valuable and desirable. There was, however, an almost unanimous feeling among the executives that collaborative R&D would encounter legal barriers under present antitrust laws. The recent guidelines issued by the Antitrust Division of the Department of Justice show that, on a case-by-case basis, arrangements satisfying the requirements of the department can be worked out. The Smelter Control Research Association, which conducts cooperative reseach on generic problems, is a good example. Nevertheless, as long as industry executives perceive antitrust laws and policies as a barrier, these will continue to be a disincentive to collaborative development of technology.

Implementation of a technical development plan is the final step of the innovation process and the only proof that the process has taken place and is of value. To facilitate implementation, whatever programs are undertaken must have the full acceptance and the close participation of the managements of the companies that make up the mineral industries. The role of government must be one of encouragement, of removing disincentives to innovation, and of working cooperatively with the industries on mutually beneficial projects. Whatever government programs are developed must, address both the climate for investment and the institutional means for RD&D support.

A constructive relationship will have to be developed between the mineral industries and government in this country perhaps similar to that between heavy industry and government in Japan. It must be realized that such industry-government relationships in other countries form the foundation of much of the competition to the U.S. mineral industries. U.S. domestic industries are basic to the health of our economy. If government assumes a more active partnership role, communications between government and industry and actions resulting from these communications can be coordinated to stimulate innovation in mineral technology in the national interest.

As part of its partnership role, the federal government's mission as regulator should be modified so that regulations foster technological innovation. For example, environmental, health, and safety regulations are usually designed around existing technology and not uncommonly specify precisely how a particular objective must be met. As a result, R&D programs aimed at the problem are circumscribed in scope and produce add-on conventional technology rather than innovative developments.

Clarification of national goals and policies relative to import dependence and reduction of economic and strategic vulnerability will also help target new avenues of desirable technological advance.

Patents are generally not seen as being of great value to the mineral industries. While there are examples to the contrary, such as the patented ASARCO shaft furnace for melting copper cathodes, the mineral industries generally do not see licensing of technology as a significant source of revenue--partly because of the poor protection offered by patents and partly because of the lack of emphasis on new technology in the conduct of industry business. Thus, neither patents nor the potential revenue from licensing is a significant incentive for technological innovation in these industries.

Many countries use tax policy to accelerate technological innovation. In Canada and Japan an annual write-off of 100 percent or more on both operating and capital expenditures for R&D has proved useful. Other tax measures include deductions of expenses incurred in the licensing of new technology, tax credits for increases in R&D expenditures (operating and capital) over a base period, and accelerated depreciation on new plants and equipment for projects involving newly developed technology. The Committee feels that tax policy can be a powerful tool both in providing direct incentives for technological innovation and in offsetting disincentives currently influencing the industry. For a fuller discussion, see the NRC report The Impact of Tax and Financial Regulatory Policies on Industrial Innovation (NRC 1980b).

On the basis of the above conclusions, the Committee makes the following recommendations to all who share responsibility for the development and use of new mineral technology.

RECOMMENDATIONS

A large number of actions are available through which the application of technological innovation in the domestic mineral industries might be enhanced and through which cooperative activities among private industry, the federal government, and academic and other institutions could be developed to improve the technological base of the domestic mineral industries. The Committee believes the following suggested actions are especially pertinent. (See also Appendix B, which lists recommendations of the Subcommittee on Mines and Mining of the Committee on Interior and Insular Affairs, U.S. House of Representatives, 96th Congress, relative to lessening U.S. mineral vulnerability).

Mineral Industries

1. Establish, with the aid of existing industrial associations and professional societies, highly effective industrial research consortia for the various mineral industries for the purpose of (1) solving common technological problems, (2) providing an interface with the federal government on mineral matters involving technology, and (3) establishing an interface with universities in the area of mineral technology.
2. Assist the Bureau of Mines in assessing the national R&D needs in the minerals area.
3. Work closely with the Bureau of Mines in identifying high-risk mineral resource projects that require government input and cost-sharing and are vital to the nation's defense and economic security. Enter into cost-sharing agreements with the government to pursue the solution of such high-priority technological problems.
4. Promote strong ties with academia. Promote and support education and training of outstanding researchers and engineers interested in the problems of the mineral industries. Upgrade the labor force of the individual companies to handle higher levels of technology.
5. Emphasize technological innovation throughout the mineral industries as a necessity if revitalization of the industries is to take place.

Federal Government

1. Formally designate the Bureau of Mines as the lead federal agency and the recognized focal point for the mineral industries' interactions with the federal government.
2. Direct the Bureau of Mines to develop and maintain, through a representative advisory board and the close assistance of industry and academia, assessments of national R&D needs in mineral supply problems.
3. Charge the Bureau of Mines, in cooperation with the Department of Defense, the Department of Commerce, other concerned federal agencies, and the mineral industries with identifying high-risk mineral resource projects that are vital to the nation's military and economic security. Develop and implement mechanisms whereby cost-sharing and cooperative efforts between government and industry can be made effective.

4. Authorize the Bureau of Mines, in concert with the various sectors of the mineral industries, to identify those tax, patent, and regulatory incentives that would be most beneficial in revitalizing the mineral industries and assist it in regaining its earlier competitiveness. Examine present regulations from both a societal and cost-benefit basis to minimize negative impacts. Direct constructive recommendations for initiating such incentives and streamlining governmental procedures to appropriate Congressional committees, federal departments, regulatory agencies and officials.

5. Instruct the Bureau of Mines to work closely wherever appropriate with the industrial research consortia developed by the various mineral industries.

6. Promote constructive interactions with qualified universities through financial support of educational and research programs.*

Universities

1. Establish strong liaison with the mineral industries and the Bureau of Mines. Secure close working relationships with the various industrial research consortia on technical problems identified by the mineral industries and the Bureau of Mines.

2. Actively recruit outstanding students and prepare them for a future in the mineral industries. Develop meaningful training programs for these students that stress innovative approaches.

Professional Societies

1. Assist in the development of appropriate industrial research consortia for the various mineral industries. Provide objective input to government and the public on status, concerns, and problems of the mineral industries relative to military and economic security of the nation.

2. Strengthen the quality of educational programs and publications in the areas of mineral science and engineering.

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*Such support is already authorized under: (a) state mining and mineral resources research institute programs (PL 95-87, 30 USC 1221 et seq.), and (b) domestic mining, mineral, and mineral-fuel conservation fellowships program (PL 89-329 as amended, 20 USC 1134 et seq.).

APPENDIX A

Highlights of Report "U.S. Minerals Vulnerability: National Policy Implications", Subcommittee on Mines and Mining of the Committee on Interior and Insular Affairs, U.S. House of Representatives, 96th Congress

If the United States truly expects to maintain its economic strength; to meet tomorrow's more sophisticated challenges; to improve the quality of life of its citizens, as well as that of others: and to regain the leadership expected by the free world, it must return to a clearer realization of the indispensable role that mineral raw materials, and the technology that is so intimately a part of their use, play in the economy.

A vast majority of the United States citizens do not understand the role of minerals in the human environment in which they are intimately involved. Their homes, their travel to and from work, their places of employment all depend upon nonfuel minerals.

It seems that the further American's have collectively moved from raw materials production, the more that production is taken for granted. The more visible are the products of mining in our lives, the less is our appreciation of the need of mining.

America has developed a store-shelf mentality, expecting all that we need to appear somehow in the quantity and quality necessary, at the time and place of demand. Meanwhile we are swept along by advocates of policies that not only reduce our productive capacity but increase our reliance on others.

Yet despite the hard lessons now being learned as a result of foreign energy dependance, little attention is being paid to the consequences of increasing nonfuel mineral dependence.

The Committee is well aware that the United States cannot be totally self-sufficient in all minerals, and that the inter-reliance of nations on the free movement of minerals in international trade will of necessity remain a vital component of supply. However, the United States remains a mineral-rich country. It is in the best interest and to the advantage of the United States and to its allies to encourage industry to maximize its mineral investments within the Nation's borders.

America cannot assume as it did with energy that adequate mineral supplies will somehow be there waiting for us when we need them.

Past Studies on Minerals Policy

There have been no less than 20 mineral or material policy studies that have been prepared or commissioned by one governmental agency or another, as well as others prepared for groups outside government.

Although many studies reflected some particular outlook or condition, all adopted as a universal starting point the national significance of adequate mineral supply and the importance of a strong domestic industry. All agree, to a greater or lesser extant, that foreign imports provided least-cost benefits to the consumer. At the same time, most see the pitfalls of import dependency and how such dependency forfeits freedom to make political, economic, and defense decisions.

The most obvious conclusion that can be drawn from the various reports on mineral policy is the correctness and utility of the Mining and Minerals Policy Act.

The decline of America's mineral producing capabilities and all that it portends is not the result of the Mining and Minerals Policy Act's lack of specificity, but rather a deficiency on the part of those who have failed to understand its importance. Congress too has played a role in the decline of America's mineral capabilities, because of its fragmented policy process. Congress has failed to provide oversight, has not sought to understand how other legislation negatively affects the production of minerals, and has failed to check executive initiative oriented only toward other, and often conflicting, policy goals.

Another conclusion to be drawn from the reports of the last 10 years, is that they have made no imprint on the formation of executive policy, which, out of a concern for the attainment of other national goals has given little or no priority to the Nation's minerals. Few have yet to realize that, whether in the pursuit of improvements in the quality of the environment, assistance for developing countries in attaining larger shares of the earth's resources, or achievement of no growth or a lower living standard for the United States, any group of actions that by cumulative impact weaken America's ability to produce its minerals will exact a price that the citizens of this country may well not want to pay.

The Mining and Minerals Policy Act of 1970

In the past, government's most direct role in mineral policy implementation has been in reaction to massive mineral requirements for wartime or to major unforseen changes in external supply.

What has been lacking for ten years is neither policy nor effectuating tools but rather, desire and will.

Notwithstanding the clarity of the statutory language of the Mining and Minerals Policy Act of 1970, and the fundamental purpose of its accompanying legislative history, the Department of the Interior had chosen, for a full decade, to abdicate its assigned role and responsibility. Interior has a long record of benign neglect regarding the mining and minerals industry.

In the face of an unequivocal Congressional directive to do so, the Interior Department has made no effort to develop a system for identifying, quantifying, and evaluating the impact of proposed Federal actions on the Nation's nonfuel minerals resources. The result is that minerals now stand alone as the most neglected U.S. renewable and nonrenewable resources not to mention national policies.

Perhaps no single action by the Department of the Interior illustrates its abdication of the Mining and Minerals Policy Act of 1970 as do the annual reports issued under that statutory mandate. Initially comprehensive and at least willing to acknowledge the duties and responsibilities assigned under the Act, the reports have degenerated into a perfunctory and totally unsatisfactory fulfillment of the form but not the substance of the requirements of the Act.

It is long past time for the Department to take seriously the Congressional mandates of the Mining and Minerals Policy Act of 1970.

The Department of the Interior with its preeminent concerns for other resources, has been woefully negligent in the performance of its responsibilities regarding the Nation's minerals. The Department has blatantly ignored the findings and recommendations of numerous expert studies on minerals policy stretching over the past 30 years and has abdicated its responsibilities in implementing the single existing Congressional statement of national mineral policy—the Mining and Minerals Policy Act of 1970.

The Nonfuel Minerals Policy Review

The entire effort was a tragic waste that cost American taxpayers about $3.5 million and the loss of some 13,000 person-days.

The review provided an ideal mechanism for the executive to examine the host of problems regarding this issue from the divergent viewpoints of the various domestic and foreign policies so as to determine the direction necessary in the years ahead to maintain the strong mining industry, which is critical to the economy and national defense.

The Nonfuel Minerals Policy Review was doomed from the outset because of the lack of priority given to it by the administration.

Its failure also highlights the deficiencies of the administration's domestic policy review system.

A major conclusion that can be drawn from this frustrating, unproductive exercise is that the executive policy mechanism does not possess even arguable merits for coordinating major policy questions.

Government's Decisions and Minerals Availability

Over the past decade the development of ore deposits in the United States has become increasingly de ndent upon decisions of government—a government increasingly opposed to such development. In fact, in some cases, the Federal Government's opposition to mineral development has been accomplished by the open solic·-ation of public opinion against such development. In other instances, government's inertia and predisposition in favor of nondevelopment must be overcome by evidence which often amounts to "proof beyond a reasonable doubt." As a result, the assumption by the Federal Government of the role of final arbiter and decisionmaker has made mineral development and production difficult. time consuming, and costly, and in the end often impossible. The Nation's mineral security has thereby become dependent, not upon the free market system, but upon the political process.

It is not so much that coordination has not improved in almost 30 years or even that government's ability to complicate coordination has made the situation exceedingly worse, but rather that today there is absolutely no Federal policy-level advocate for minerals.

There must be somewhere in government a willingness and the capacity to grasp the seriousness of U.S. mineral shortfalls that certainly lie ahead if the Nation continues on its present path.

U.S. Government policy decisions regarding mineral pricing are shortsighted, contradictory, and change according to circumstances and the government agency involved. Government's control of mineral prices during periods of inflation reflects little understanding of cyclical international markets or of the fact that such control inhibits the ability of U.S. mineral producers to recover from periods of low prices. At the same time, government antitrust policies prevent U.S. producers from jointly discussing such matters with each other or government agencies.

On the one hand the Justice Department and the Federal Trade Commission believe that prices should be established competitively in open markets, presumably without regard to the social consequences of sharply fluctuating prices. On the other hand, the State Department worries only about the effect of fluctuating prices on the economies of developing countries.

Good mineral policy should not be a policy of reaction, but rather the product of a steady commitment that recognizes the indispensability of minerals to the Nation's industrial base and its national security.

The most debilitating element of the process now unfolding is that while government planners expect industry to solve the problems, government pursues a course that make solutions increasingly difficult if not impossible to achieve.

Government can no longer stand at arm's length to the Nation's long-term mineral interests. The decision the government must make—and, of all the decisions made during the past 10 years, the one that it has refused and failed to make—is that the development of a strong and stable domestic mining and minerals industry is in the Nation's best interest.

Capital Formation Problems

U.S. Government can and should enhance the prospect of an adequate return on investment by avoiding artificial restraints on the free-market system, by undertaking economic policies that encourage capital expenditures by the mining and mineral processing industry, and by adopting a sounder priority of national goals.

For long-term survival, the mineral industry needs adequate prices and profits on the high side of the cyclical flows to offset the loss incurred on the low side. If government interferes, and by so doing deprives the industry of return on investment, the industry's ability to attract capital will be permanently impaired and its securities will remain suspect.

If the United States ever hopes to have a mining industry capable of providing the minerals essential for our economy, it is essential for government's economic policies to encourage capital investment and development in the minerals industry.

Tax Policy Problems

Federal tax laws have not kept pace with the changed circumstances confronting the mining industry. They have not accorded any meaningful recognition of the capital and operating cost burdens currently placed on that industry. Greater incentive must be provided to assist the industry not only in meeting its general capital needs for the development and expansion or productive capacity, but also in alleviating the burden imposed on the industry by mandating environmental and health and safety expenditures. Improved financial posture of the mining industry is necessary if that industry is to regain any semblance of a competitive position in world markets.

To achieve that goal, a number of actions are essential: First, that the existing, long-standing, time-proven provisions of U.S. tax laws that recognize the importance of the mining industry—percentage depletion allowances and expensing of exploration and development costs—be continued; second, that the investment tax credit, an important incentive to capital formation, be extended to include all buildings used in mining and manufacturing and be made refundable (or at least fully creditable against a company's entire tax liability); third, that realistic, flexible capital cost recovery allowances for plant and equipment investments be adopted in lieu of present depreciation allowances; fourth, that the costs of environmental and other similar government-mandated requirements be written off over any period selected by the taxpayer, including the year of expenditure, and; finally, that tax-exempt municipal bond financing be available for nonproductive pollution control abatement equipment as well as for other government-mandated expenditures.

Antitrust Enforcement Problems

In the area of antitrust enforcement one finds much the same narrow doctrinaire approach, the same tunnel vision, the sa e open disregard of a national minerals policy as is found in other governmental arenas.

In the past decade, capital costs of major new mining and mineral processing ventures have grown faster than the financing capabilities of many independent U.S. mining concerns. The traditional hostility of U.S. antitrust policies toward joint ventures hinders U.S. firms in pursuing one of the most worthwhile financing alternatives open to them.

The evidence strongly suggests that U.S. antitrust policy contains and reflects serious misconceptions about the nature of competition in the world market in which American mining companies must operate. Moreover, the evidence demonstrates that the antitrust agencies have been less than diligent in advancing the cause of free competition in several important respects. Unlike the United States, the European Economic Community and Japan, in their own interest, have significantly and realistically liberalized their antitrust laws.

In 1978, proceedings were commenced before the U.S. International Trade Commission before which copper and zinc producers sought temporary limits on imports. It is fair to say that, regarding both metals, U.S. producers were resorting to the only lawful mechanism available to bring the market forces to bear upon foreign producers. Yet, in both instances, the Antitrust Division of the Justice Department intervened on behalf of foreign producers. In so doing, the Antitrust Division appears to have been pursuing abstract principles of free access to markets, while ignoring the real threat to continued participation by U.S. firms in world markets which were and are increasingly dominated by State-owned or State-controlled enterprises. Ironically the ultimate result of the end sought for both copper and zinc by the Justice Department was not a fostering of competition in the world market but a further concentration of production in offshore subsidized operations.

Notwithstanding the long-term impacts of such regulations there does not appear to be a single instance in which the Antitrust Division argued, in proceedings of these agencies for a more balanced regulatory approach so as to increase domestic s pply in order to preserve competition.

If the domestic mining and minerals industry is to survive so as to provide U.S. citizens the domestically available minerals, reversal of this counterproductive approach by the Department of Justice and the Federal Trade Commission must become part of broader national goals.

Environmental and Health and Safety Regulations

This trend toward environment enhancement at any cost, regardless of economic impact, has led to excessive and unreasonable regulations which today threaten to stifle private enterprise and to cripple the basic industries of America, particularly the mining and minerals industry.

Congress is further to be faulted for its inability and unwillingness to make the difficult decisions demanded by environmental versus development concerns, instead adopting statutory mandates that are frequently expressed in ambiguous, inconsistent terms and phrasing thus providing fertile ground for the promulgation of regulations by Federal agencies.

Thus environmental, health and safety goals conflict with the objectives of national minerals policy not by their nature, nor their desirable objectives but through uncertainty, delay, excessive costs and the snuffing out of innovative approach to problem solving—which has been a hallmark of the U.S. free enterprise system.

Probably the most difficult concept for this Committee to grasp is the expectation by government regulators that they will settle for no less than perfection. The whole world recognizes intuitively that perfection is rarely attainable in anything, but environmental and health and safety regulators refuse to even consider the alternative of "an acceptable risk."

Environmental controls, regardless of the desirability of their objectives, cannot long continue to operate in total disregard of the economic feasibility of their attainment. The Federal Government as a fundamental aspect of national minerals policy, must seek balance between the environmental, health and safety statutes and regulations on the one hand, and the need to ensure the reliable availability of strategic and critical minerals on the other. The flaw most obvious in the executive mechanism, once again, lies in the total absence of a responsible official to advocate balance or, at a minimum one who understands and shows an interest in the essential need for a strong U.S. minerals posture.

Public Land Access Problems

Given the anomalous nature of economic mineral deposits and the continuing need for domestic supplies of nonfuel minerals, it would seem natural that the government would encourage new exploration in the United States. Instead government policies have proved to be counterproductive to the discovery and the development of mineral deposits.

The United States still knows little about the total mineral resource potential of its land. However, the discovery of mineral deposits is no longer a matter of relying on the abilities of exploration crews to find such deposits. The most precious asset and the most fundamental requirement, access to land—primarily the mineral-rich public land—in which to search for minerals could well become the scarcest component in America's mineral supply future.

The most deplorable aspect of this shortsightedness is that it is being done without knowledge of the losses involved, without any attempt to understand long-term impacts, and without any government accountability for the consequences. Over the last 10 years the United States has made grave, fundamental errors in administering the public lands with respect to minerals despite the provision in the organic acts of the principal land managing agencies of adequate authority for mineral development.

This growing denial of acces for mineral exploration development is aggravated by the total lack of interest within the executive for specifically determining the availability of public lands for mineral development.

The scarcity of information of mineral resources has been used by the Department of the Interior—the Nation's chief manager of Federal minerals—as a reason for not considering minerals.

Technological Innovation Problems

There is frightening evidence that U.S. industry, as a whole, is losing its edge in technology and, as a result, in productivity. This is due in large part to the cumulative impact of government's regulatory, tax, and antitrust policies and more generally, to the absence of a reasonably stable investment future as a result of the uncertainties of inflation. The consequence has been a decline in the competitivenes of American industry in general and of the mining industry in particular, which in turn has discouraged capital formation and prevented the profits necessary for investments in innovation.

The special nature of commodity markets, the unknowns of future supply and demand forces, and uncertainty of prices that are determined in international markets have all acted as constraints upon innovation in the minerals industry. Large investments in existing capacity and the long life necessarily designed into that capacity—which seldom can be replaced with existing cash flows—mean that innovation spreads slowly within the industry. Perhaps the major deterrent to innovation is simply the cost and time needed to prove new technology on scales large enough to be meaningful. The uncertainty of outcome and the high risks involved in demonstrating large scale innovative concepts has discouraged efforts by individual companies. This is at least one responsibility that must be shared between the public and private sectors.

Foreign Mineral Dependence

To the extent that a country is dependent on import sources for its basic raw materials, its economy can be held at ransom by an association of exporting countries—whether instituted by political or economic concerns—determined to manipulate prices to their advantage. Control, in the full sense of a cartel—an organization with the ability to artificially maintain high prices or deny supplies over a long period of time—is unlikely except possibly for chromium and platinum group metals. Nevertheless, producer associations, particularly during periods of short supply and rising prices, will increasingly be capable of exacting higher pri es. In addition, they may well be willing and able to restrict supplies to certain consuming nations for political purposes. The ability to undertake cartel-like action is enhanced by the shift in world ownership patterns of several important nonfuel minerals whereby governments themselves, with their own particular goals and objectives not necessarily involving profit, have assumed ownership of important parts of the mineral sector. Moreover, the failure to fully appreciate the growing sophistication of producer strategies and the dangers they pose renders impotent America's ability to alter and correct past mistakes and to develop alternatives.

No agency or department within the U.S. Government is today weighing the worldwide lag in ew mineral development, the growing lead times for development, and the effects of inflation on such developments against increasing world demands and, most importantly, U.S. Government poli ies that are, in effect, promoting offshore reliance. The only possible conclusion is that the executive is simply not planning for long-term mineral needs of the U.S. economy and its defense. It would certainly appear that the responsibility for the assurance of long-term foreign supplies is too important an objective to lie solely within the Department of State whose foreign policy interests appear to subordinate domestic and even national interests in this area. The foreign policy of the U.S. Government has failed to evidence a basic responsibility for the adequacy or costs of mineral imports. American foreign policy has disregarded both America's legitimate mineral interests abroad and the security of mineral access—even in the subarea of economic policy.

There are extremely serious security implications currently being ignored in the Federal Government's inconsistent approach to mineral adequacy. Mineral , essential to the production of military hardware, and its industrial base, are of vital importance to the Nation not merely in times of international tension but at all times so as to minimize existing vulnerabilities and forestall crisis provocation. This is particularly true if the source nations for such materials are either potential adversaries or politically unstable. The United States will be incapable of fulfilling mutual security commitments if a significant part of its energies must be expended to guarantee the flow of critical mineral resources essential to mere national survival.

The stockpile today relative to some important commodities is neither of adequate q ality nor quantity. Holdings of some vital materials are far below present objectives, and for some there are no holdings at all.

APPENDIX B

Recommendations of Report "U.S. Minerals Vulnerability: National Policy Implications", Subcommittee on Mines and Mining of the Committee on Interior and Insular Affairs, U.S. House of Representatives, 96th Congress

The United States must begin today to put an end to the self-defeating nonfuel minerals non-policy that is crippling the United States mineral industry, increasing national dependence on foreign sources, and placing in jeopardy the Nation's economy, defense and world stature. The very first step, however, is to develop a commitment on the part of the United States Government and its leaders for an effective national minerals policy.

National Minerals Policy

The Nonfuel Minerals Policy Review, initiated in December 1977, should be revised and completed, culminating in a Presidential decision document.

The Mining and Minerals Policy Act of 1970 has not been an integral part of national policies and goals and should be fully implemented as intended.

The Assistant Secretary for Energy and Minerals, Department of the Interior should faithfully fulfill the responsibilities as the energy and minerals advocate within the Department of the Interior and the executive.

The President should create, within the Office of Management and Budget or the Executive Office of the President, an Office of Energy and Minerals (OEM). This office should be provided with the same stature, power, and oversight responsibilities as the Council on Environmental Quality (CEQ). This office should ensure that the Nation's mineral needs and resources are adequately considered in all actions and decisions of Federal agencies and departments.

FEDERAL LANDS

The Congress should recognize and consider in the adoption of public land classifications, which would prohibit or restric mineral exploration and development, the essential role of those lands in assuring domestic supplies of minerals, the relatively low state of knowledge regarding their mineral potential, and the ever changing characterization of mineral potential given technological advances. The Congress should therefore exercise extreme caution in the passage of such legislation.

The Department of the Interior, as a general policy, should make public lands more accessible for mineral exploration and development.

The Department of the Interior should make a full review of all Federal actions relative to public lands to determine the status of those lands with respect to their availability for mineral search and development. The review should be completed within 3 years and be independent of the withdrawal review mandated by the Federal Land Policy and Management Act. Such information is vital in order that Congress may make fully informed decisions with respect to the public lands.

The Department of the Interior should take fully into account in the development of restrictive land classification recommendations and decisions the mineral resource data and estimates of potential made available by the Bureau of Mines and United States Geologic Survey recognizing that government surveys lead to few discoveries and thus do not constitute exploration in its truest sense.

The Department of the Interior should implement the mineral assessment provisions of the Federal Land Policy and Management Act of 1976, the Strategic and Critical Stockpiling Act of 1946, and the Wilderness Act of 1964.

The Wilderness Act of 1964 should be enforced to permit full exploration and development of nonfuel minerals in accordance with the intent of 4(d)(3).

The Wilderness Act of 1964 should be amended to permit mineral exploration upon wilderness lands through the year 2000, and for wilderness created after 1980, for a period of 20 years.

Mineral values of public lands should be placed on a priority at least equal to the environmental concept of "areas of critical environmental concern" and other similar classifications. The rarity of a mineral occurrence necessitates the adoption of a concept of "areas of strategic mineral potential" whereby mineral areas would be so designated and hence protected from restrictive classification.

Capital Requirements

Low-cost pollution control financing should be made more available by permitting eligibility despite incidental recovery of mineral byproducts.

Industrial revenue bond financing should be made available for mineral activities costing more than $10 million.

Percentage depletion allowances and expensing of exploration and development costs should be continued.

Investment tax credit should be extended to include all buildings used in mining and manufacturing and made refundable or at least fully creditable against a company's entire tax liabilit .

Realistic, flexible capital cost recovery allowances for plant and equipment investments should be adopted in lieu of present depreciation allowances.

The costs of environmental and other government mandated requirements should be permitted to be written off over any period selected by the taxpayer including the year of expenditure.

Tax-exempt municipal bond financing should be available for nonproductive pollution control equipment as well as for other government-mandated expenditures.

Antitrust

The Executive should undertake a re-examination of the manner in which antitrust laws have been implemented recognizing that the adversarial relationship between the Executive and the minerals industry must end.

The Executive should revise and modify antitrust policy as necessary to promote cooperative government and industry research and development and informed participation at international minerals forums.

Environmental Standards

The Congress should more definitively specify the objectives of environmental legislation because broadly written, ambiguous goals provide little real direction while allowing for administrative misinterpretation or abuse of legislative intent.

The Congress should, in the adoption of environmental legislation, link the goals sought with the costs involved to provide that standards will be economically attainable.

The Executive should place a moratorium on the issuance of additional regulations in order to ascertain the cumulative impact of such regulations on the minerals industry and ensure that such regulations require the attainment of reasonable standards based on provable data.

The Executive, in the preparation, creation and promulgation of environmental standards should balance the environmental objectives sought with the cost involved. As well, the Executive should enforce performance rather than design standards so as to fully utilize the innovative potential of America's private enterprise.

RESEARCH AND DEVELOPMENT

Federal mineral supply research and development should be significantly increased to reestablish United States leadership in technological innovation and to improve recovery and productivity in the minerals sector.

Increased levels of support should be provided colleges and universities engaged in extractive technologies research.

A program should be devised for government to more effectively contribute to demonstration projects to prove new technologies.

The 31 Mineral Institutes established by the Department of the Interior at colleges and universities should be transferred to the Bureau of Mines to improve mineral supply research and development cooperation.

FOREIGN POLICY

Foreign policy should include the legitimate economic interests of the United States as a significant element of its national security interests.

An economic strategy relative to foreign nations should be developed to give higher priority to mineral resource aspects, of foreign relations as a means to manage and limit resource vulnerability.

Foreign policy should have as a goal reliable access for United States mineral investments for national economic security. Foreign aid as an aspect of foreign policy should be directed toward this goal.

The United States should work to reestablish traditional economic concepts under international law.

The United States should exercise care when imposing U.S. environmental prerequisites on foreign mineral investments if imposition of standards will result in the loss of economic benefits to the developing country.

NATIONAL DEFENSE

The Department of Defense can no longer act as a consuming bystander regarding national minerals policy. Instead, the Department of Defense should become involved within the Executive so as to ensure secure and stable sources for the mineral needs of the Nation's defense systems. The surest source of minerals in times of crisis is a domestic source.

APPENDIX C

ROLE OF THE PUBLIC AND PRIVATE SECTORS IN FOREIGN COUNTRIES AND THE IMPACTS OF TECHNOLOGICAL INNOVATION

The experiences of other countries with industrial innovation is somewhat different from that of the United States and may offer some ideas on institutional arrangements that might be adaptable to U.S. mineral technology problems. What emerges as an important element in the pursuit of technological innovation is not the amount of money spent on R&D but the arrangements under which is is spent. The United States is said to be lagging behind foreign countries in technological innovation even though it generally spends a greater percentage of its GNP on R&D than most other countries (see Table C-1). The following discussion describes the arrangements and various approaches to technological innovation that have been implemented in a number of foreign countries.

JAPAN

Japan's amazing progress in technical innovation has made that country internationally competitive in a number of areas, especially the mineral industries. Japan is not well endowed with mineral resources, yet the country is a major factor in the world mineral enterprise. According to the U.S. Bureau of Mines (1977), mineral raw materials constitute about half of Japan's imports, and processed mineral and metal products constitute a quarter of its exports.

Most Japanese industrial and mining companies are privately owned and rather competitive; yet they are often interrelated and commonly work together, particularly when developing new projects abroad. Japanese industry is accustomed to involvement with government, which establishes policy guidelines, provides tax incentives and sometimes low-interest loans, can assume some exploration and development risks, loosely regulates production and trade, and suggests stockpiling objectives. R&D in minerals and metals are strong in industry, government, and universities. Overall, the Japanese mineral industry is up-to-date by world standards and, in many respects, surpasses that of the United States.

TABLE C.1 R&D Expenditures in Six Industrial Countries

Country	Percentage of total funding from		Percentage of GNP
	Industry	Government	
Canada	33	67	0.9
France	41	59	1.7
Japan	68	32	1.9
United Kingdom	42	58	1.9
United States	47	53	2.2
West Germany	62	38	2.4

SOURCE: National Planning Association (1978).

Japanese technology policy is distinguished by its complete identification with economic-growth policies, particularly in industries with high-value export potential. Through a practice known as "targeting," the Ministry of International Trade and Industry (MITI) selects industries to be favored according to their potential for development and export business. The favored industry is encouraged to invest in selected enterprises through incentives such as accelerated depreciation of new equipment and tax deferment. The Bank of Japan makes it easier for commercial banks to obtain funds when their loan policies are in accordance with government priorities--i.e., when loans are made to companies selected for development. In both Japan and Europe the debt-to-equity ratio is usually higher than in the United States. For Japanese companies, for example, the ratio is typically 3 or 4 to 1, whereas for U.S. companies, it is closer to 2 or 3 to 1. Further, under the Japanese banking system the cost of borrowed capital is less than that obtained from the sale of stock.

Expenditures by the government for the development of new technologies do not seem to be proportionately greater than those of the U.S. government: typically, the ratio of government to industry funding is 40 to 60. However, the government-mandated cooperation among certain companies at the level of basic research strongly contrasts with U.S. policy. In Japan, moreover, government emphasis is on consumer technologies responding to market demand, as opposed to the U.S. emphasis on "big science" and national prestige projects. And Japan places heavy emphasis on technical education and the training of highly skilled manpower. This, coupled with Japanese labor's positive attitude toward production and productivity, has helped the country to outstrip the United States and the European countries in the production of technology-based consumer products.

The steel industry of Japan is an interesting example of the effect of these policies. The following is from a report of the National Research Council (NRC 1978a):

> An important factor in the six-fold expansion of the Japanese steel industry after 1960 was its designation by the government as one of the key industries in the national plan for industrial development and export expansion. Through its control of allocations, the government ensured the availability of capital required for the industry's construction of new facilities. Thus, eight new plants were built, each averaging nearly 10 million tons per year of capacity, whereas the United States built only one fully integrated steel mill (with a capacity of less than 6 million tons) in the same period of time. In turn, the construction of these plants permitted incorporation of the latest technological advances and the fullest economies of scale. It also spawned further developments along the same lines for application in the planned next generation of new plants.
>
> The government's award of elite status, combined with the steel industry's own intensive technological image and its

expanding promotional opportunities, helped to attract leading university technical graduates, thereby increasing the likelihood of continuing technical advances. The development of the steel industry's technological capabilities also was encouraged by the government's permissive attitude toward increased concentration of the industry in the interests of exploiting economies of scale and also allowing leading producers to cooperate in procuring raw materials and expanding and supplying foreign materials so as to ease competitive pressures during domestic recessions.

Another powerful contribution to advancing the technological capabilities of the Japanese steel industry was the support of such efforts by the top managements of the leading companies. That support was noted not only in profit motivations but also in deep commitments to three distinct objectives: (l) building the power and prestige of Japan, (b) minimizing dependence on foreign technology, and (c) emphasizing long-term performance objectives.

GREAT BRITAIN

Research Associations

As early as 1917, the British government perceived a need for government-industry relations in the area of technological innovation and implemented a scheme of publicly supported industry research associations that exists to this day. Table C-2 lists the industrial research associations that have been formed since 1917.

Under the research association scheme, the government makes a grant, typically about 20 percent of the total income of the association (although for newer associations the proportion can be higher) to initiate an association of companies within an industry. The grants are not tied to any contract, specific project, or direction of research. A grant is offered for a period of five years and is renewable as long as the research association is performing according to certain minimal standards. The viability of a research association depends upon the industry's willingness to provide the remainder of the funding for the association. Annual dues to the association are determined by some measure of the size of each member company relative to the remainder of the industry. Each company's commitment, like the government's, is for a period of five years. Table C-3 summarizes the financial status of the British research associations for 1968 and 1970.

The most useful purposes that research associations serve have been identified (Woodward 1965) as:

- The encouragement of cooperation in R&D among members of an industry and the effect of making the entire industry more research-conscious.

TABLE C.2 Government-Grant-Aided Industrial Research Associations in Great Britain in 1964

Name of research association	Date formed
British Banking	1946
British Boot, Shoe and Allied Trades	1919
British Brush Manufacturers	1946
British Cast Iron	1921
British Ceramic (Formed from British Refractures, founded in 1937)	1948
Civil Engineering	1964
British Coal Utilization	1938
British Colliery Owners	1920
British Coke	1944
Cotton, Silk and Man-made Fibers	1919
Cutlery and Allied Trades	1962
Drop Forging	1960
Electrical	1920
British Hat and Allied Felt Makers	1947
File	1956
British Flour Makers	1923
British Food Manufacturing Industries	1946
Fruit and Vegetable Canning and Quick Freezing	1952
Furniture Industry	1961
British Gelatine and Glue	1948
British Glass Industry	1954
Heating and Ventilating	1959
Hosiery and Allied Trades	1949
British Hydromechanics	1947
British Industrial Biological	1960
British Internal Combustion Engine	1943

TABLE C.2 (Continued)

Name of research association	Date formed
British Iron and Steel	1944
British Jute Trade Association	1946
Lace	1949
British Launderers	1920
British Leather Manufacturers	1920
Chalk Line and Allied Industries	1955
Linen Industry	1919
Machine Tool Industry	1960
Motor Industry	1945
British Nonferrous Metals	1919
British Paint, Color and Varnish Manufacturers	1926
British Paper and Board Industry	1945
Printing, Packaging and Allied Trades	1930
Production Engineering, of Great Britain	1946
Rubber and Plastics, of Great Britain	1919
British Scientific Instrument	1918
British Ship	1945
String Manufacturers	1961
British Steel Cushings	1953
Coal Tar	1949
Timber Research and Development	1962
Water	1953
British Welding	1946
Whiting and Industrial Powders Research Council	1948
Wool Industries	1918

SOURCE: OECD (1967).

TABLE C.3 British Government Support for Research Associations (General Grants)

	1968	1970
Total government grant support	£4,033,107	£4,021,137
As percentage of total RA income	26.6	24.5
Average grant per RA	£93,793	£93,515
Number of RAs with income from governments grants		
over 40 percent	2	3
34 to 40 percent	9	4
26 to 33 percent	11	15
21 to 25 percent	12	9
15 to 20 percent	5	8
under 15 percent	4	4

SOURCE: Center for the Study of Industrial Innovation (1972).

- The investigation of problems of special interest to a large segment of an industry that cannot be conveniently or economically performed by single members.
- The transmission of new research ideas and technical knowledge to members from a variety of sources.
- The stimulation of innovation in small- and medium-size firms without research facilities of their own.
- The reduction in costs and the conservation of scientific and technical manpower that result from cooperative research.

Shortcomings in the functioning of research associations, according to several studies, are:

- The proportion of the total industrial expenditure on R&D that is spent on research associations is generally "infinitesimal," and thus many research associations are too small and too poor to be very effective (Woodward 1965).
- Work done by research associations is usually not very glamorous and seldom results in immediate payoffs or even easily measurable results. This is partly because of the nature of the research to which the cooperative approach is best suited--i.e., research devoted to improving the basic technical knowledge of an industry's production process. In addition, there is a tendency for members to give their research associations their own long-standing problems (Woodward 1965).
- Because of differences in size, management skills, and investment resources, member firms cannot equally utilize the results of cooperative research (Center for the Study of Industrial Innovation 1972).
- At any one time, some sectors of the membership may be discriminated against, since it is impossible to run a research program to satisfy all the members. Smaller firms without their own facilities tend to favor research related to short-term trouble-shooting, while larger, better equipped firms are more likely to support longer-term basic research, which can provide the basis for their own work (Center for the Study of Industrial Innovation 1972).
- A research association's research program may become dominated by strong personalities on the governing council or by especially powerful sectors in an industry (Center for the Study of Industrial Innovation 1972).

In spite of these shortcomings, work done by research associations is considered valuable, although few research associations have generated commercially exciting results.

Other Programs

Recently Great Britain established several programs designed to assist new technologies to the commercial stage:

- National Research Development Corporation (NRDC), a public corporation supporting innovation through such actions as paying all or part of the development costs of an invention, licensing public sector technologies, or entering into joint ventures with national private companies.
- Launching Aid, a program designed to reduce commercial risk to manufacturers by interest-free loans to developers of new technologies. This program has been used more for government-designated projects than for private market initiatives.
- Preproduction Order Support Program, a program whereby government-purchased and -owned production equipment is loaned to selected industrial users. This program has mostly benefited the machine-tool industries by the introduction of numerically controlled machine tools.

The Coal Industry

Great Britain's only important mineral resource is coal. The British coal industry, however, has not been an effective innovator in coal technology despite government involvement and support over the past three decades (Harlow 1977). The most important reasons why the British coal industry has had limited success in technological innovation are: the long-term neglect of the industry, the increasingly difficult geological conditions affecting mining economics, and labor-management problems.

Since nationalization of the industry in 1947 the most important innovation has been the development by laboratories of the National Coal Board of a coal mining technique known as the Remotely Operated Longwall Face (ROLF). But the installation and testing of the ROLF system in an operating mine demonstrated that although automated and remotely controlled mining was feasible, it was impractical with the limited control technology available. Pending the long-range development of advanced automation, sensing, and remote-control technology, R&D efforts were focused on improvements in productivity utilizing existing equipment appropriately modified as control technology evolved. Productivity did increase but not to the extent expected. Recognizing that further improvement in production would have to come from advanced mining systems, the National Coal Board in recent years has accelerated R&D expenditures on the development of integrated mining systems based on remote and automatic control. The centralized direction of the RD&D program (presumably conducted under pressure to yield maximum gains in productivity in the shortest possible time) has led to a concentration of effort on systems applicable only to Great Britain's thickest coal seams. The new technology has tended to "high grade" Great Britain's coal resources.

An MIT study for the Office of Technology Assessment (OTA 1978) on government involvement in the innovation process points out that the British example contrasts sharply with the Japanese in most respects. British technological policy has not succeeded in establishing positive industry-finance-government partnership and has had less relation to the economic growth strategy of the country than Japanese policy. Whatever scheme is adopted for stimulating technologic innovation in the United States should give special emphasis to establishing a progressive partnership between government and the mineral industries for the purpose of supporting a growing economy.

AUSTRALIA

Government

R&D in support of Australia's industry is performed by the Commonwealth Scientific and Industrial Research Organization (CSIRO), which was chartered under the Science and Industry Research Act of 1949 (amended in 1978). As summarized in the CSIRO Annual Report for 1978/1979 (CSIRO 1979), the basic responsibilities of the organization are:

- scientific research and application of the results,
- overseas scientific liaison,
- research training and funding,
- research association support,
- maintenance of measurement standards, and
- publication and dissemination of scientific information.

In spite of its broad-sounding charter, CSIRO represents only a portion of the scientific research of the Australian Commonwealth. Military, nuclear, telecommunications, and other research that involves either security or a government monopoly is conducted by other organizations.

One of the major roles of CSIRO is to provide a government interface with industrial research associations. Section 9(f) of the Science and Industry Research Act of 1949 specifically states that the organization is "to recognize associations of persons engaged in industry for the purpose of carrying out industrial scientific research and to cooperate with, and make grants to, such associations." CSIRO, therefore, provides scientific and technical support to the industrial associations and, in turn, the associations assist CSIRO in fulfilling its responsibilities to carry out research to assist industry and to encourage the application of results. Among these associations is the Australian Mineral Industries Research Association.

Industry

While R&D activities are carried out by numerous companies operating in Australia, industrywide R&D is conducted under the auspices of the Australian Mineral Industries Research Association (1978).

The Australian Mineral Industries Research Association, Ltd. (AMIRA) was founded in 1959 as a nonprofit, tax-exempt association, for the purpose of identifying and solving problems of the Australian mineral industries. As of June 1977, there were 44 members of the association and 20 associate members. Members are largely mining and mineral exploration companies with operations in Australia; however, at least one mining equipment manufacturer is a member. The Australian Mineral Development Laboratories (AMDEL) is the operating arm of the association.

AMDEL performs a number of functions. It provides physical facilities for AMIRA projects. It provides a mechanism for an industry overview, and when appropriate, it cosponsors projects with CSIRO. It sponsors research at universities; and it generates information and statistics concerning the mineral industries for the use of the commonwealth and state governments. In 1977, funds for the projects sponsored by AMDEL were received from the following sources:

	dollars (Australia)	percent
AMIRA members	722,417	28
Other industry clients	553,804	21
South Australian government	787,077	30
Commonwealth government	252,558	10
Other clients	292,822	11
	2,608,678	100

Funds contributed by the commonwealth government are in kind for work performed on behalf of industry at CSIRO and are contributed as matching funds to those contributed by industry (through AMIRA) under a five-year agreement. The present agreement covering work-value guarantees at CSIRO is for a maximum of $500,000 per annum. The South Australian government has also agreed to match this guarantee of the Commonwealth government.

SOUTH AFRICA

Government

The Council for Scientific and Industrial Research (CSIR) was organized in 1945 to complement the government-financed agricultural and veterinary services and geological survey, which had been in existence since 1910. An important objective of CSIR research is to improve the economic infrastructure of the country, and therefore, much of its work is performed on behalf of the mining industry. Some recent studies (see Chamber of Mines of South Africa 1978) have explored:

- greater safety in ultradeep mines,
- the mechanism of rock bursts in deep mines,
- sink holes caused by dewatering operations in mining areas,
- new methods of gold extraction and assaying, and
- new expertise in shaft-sinking.

A second government agency, the National Institute for Metallurgy (NIM), is a statutory research organization of the South African government. The primary aims of the institute are to undertake R&D in extractive metallurgy and to serve as a public source of information on this topic, with the object of stimulating the growth and profitability of the South African mineral industry. NIM's research program is comprehensive. It employs 145 scientists and 516 technicians in nine divisions: Process Development, Ore Dressing, Instruments, Mineral and Process Chemistry, Mineralogy, Analytical Chemistry, Technical Service, Liaison and Information, and Administration. NIM is funded almost entirely by the South African government. Industry and academia are represented on both the Board of Control and the Technical Advisory Committee of NIM. The president of CSIR is an ex officio member of the Board of Control, which helps to coordinate activities between CSIR and NIM.

Industry

The principal industrial organization representing mining in South Africa is the Chamber of Mines (COMSA). The Chamber was chartered soon after the discovery of gold on the Witwatersrand

> to advance, promote, and protect the mining and other interests of its members, to regulate relations between members and their employees, to give support or grant subsidies to anybody connected with the mining industry or calculated to benefit the industry, and generally to do all things necessary, conducive, or incidental to the attainment of its objects. [COMSA 1978]

Although the Chamber was originally a gold-mining organization, membership is now open to any company registered with limited liability and engaged in the business of mining in the republic or in the business of providing administrative, secretarial, or technical services to companies engaged in the business of mining.

The Chamber is a clearinghouse for technical know-how and provides the machinery for new technological development of interest to its members. The Chamber maintains well-equipped laboratories staffed by scientists and engineers. In addition, it contracts a portion of its work to universities and to mining institutes located at universities. The Chamber's research organization comprises the following divisions and laboratories:

- The Mining Research Laboratory is by far the largest R&D group of the Chamber. Its primary objective is the development of new stoping methods and machinery for gold mining to improve productivity, profitability, and working conditions. The laboratory is divided into sections concerned specifically with geological engineering, geochemistry, rock-handling, rock-breaking, machine design, hydraulic power, electrical engineering, field studies, and field trials. The laboratory has a staff of 120, of whom 52 are professionals.

- The Mining Operations Laboratory is concerned with strata control in coal and gold mines, blasting in gold mines, and the development of planning tools for gold mines. The staff numbers 37, including 24 professionals.
- The Coal Mining Laboratory was founded in 1977 to carry out R&D on behalf of the coal producers. It was assigned 18 staff members, of whom 16 are professional.
- The Metallurgy Laboratory is responsible for mineral processing and the development of portable assay instruments. It has a staff of 41, of whom 18 are professionals.
- The Environmental Engineering Laboratory works on the improvement of the thermal environment in deep mines and the prevention of fires in mines. The staff number 21, of whom 13 are professionals.
- The Human Resources Laboratory was established in 1974 to monitor the demand, supply, and utilization of people in the mining industry; to assist in the solution of particular human problems; and to assist with the implementation of research findings and with training for new methods of mining. The laboratory has a staff of 52, of whom 38 are professionals.
- The Electronics and Mechanical Engineering Division is responsible for design and construction of new electronic and mechanical equipment for use in mines. It builds experimental equipment and, in some cases, has manufactured unique equipment for use in the industry. It has a staff of 88, of whom 15 are professionals.
- Research Services consists of two divisions, the Dust Division and the Industrial Hygiene Division. The Dust Division provides a wide variety of services related to all aspects of dust problems affecting the mining industry. The Industrial Hygiene Division concerns itself with heat physiology, acclimatization, applied physiology, and ergonomics. It includes a Biochemical Section, which is concerned with the analysis of blood, urine, and air. The unit has a staff of 56, of whom 22 are professionals.

Research reports from the Chamber are generally available only to its members, but a significant portion of the Chamber's research results are published in the open literature.

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