CHAPTER 1

Summary

Contents

List of Tables

List of Figures

CHAPTER 1

Summary

Three nations, South Africa, Zaire, and the U. S. S. R., account for over half of the world's production of chromium, cobalt, manganese, and platinum group metals. These metals are essential in the production of high-temperature alloys, steel and stainless steel, industrial and automotive catalysts, electronics, and other applications that are critical to the U.S. economy and the national defense,

With minor exceptions, there is no domestic mine production of any of the four metals, The Government maintains a material stockpile but its contents are reserved for national security purposes only. As a result, the U.S. industrial economy is vulnerable to a variety of supply disruptions that may arise in times of peace. Disruptions of supply, such as the Canadian nickel strike in 1968 and the rebel interruptions of cobalt production in Zaire in 1978, can have a major impact on U.S. industries which must, in times of shortages, either compete for limited supplies of strategic metals or limit production of products that use strategic metals. Competition for supplies can result in price increases that may eventually be passed on to consumers, while reduction or cessation of production may result in loss of market share or permanent withdrawal from some markets, weakening the competitiveness of U.S. industries.

In the longer term, there are many technical alternatives that can provide more secure sources of supply, improve the prospects for conservation and recycling of strategic materials, or speed the acceptance of substitute materials that reduce the need for strategic materials.

Few of these technical alternatives can be implemented immediately on the occurrence of a supply disruption: some are near commercialization, others require further testing and evaluation, and still others are only in the research and development (R&D) stage. Nearly all of the alternatives must overcome substantial economic and institutional barriers before their full promise to reduce U.S. reliance on southern Africa and the U.S.S.R. for strategic materials can be realized.

Government actions to assure secure supplies of metals critical to the United States have been limited largely to reliance on the national defense stockpile to ensure the availability of materials required for national defense in time of war, leaving it to the free market to provide a diversity of suppliers for the industrial economy. These actions are appropriate for normal commerce and for periods of military conflict, but they are not intended to protect American industry from disruptions of the supply of chromium, cobalt, manganese, and platinum group metals that might occur as a result of political disturbances, strikes, changes in political ideology or other non-war-related factors affecting supplier nations.

There is no single generic approach to reduce materials import vulnerability–to be effective, different actions must be taken for each metal under consideration. An overall strategy to reduce U.S. reliance on uncertain sources of supply of strategic materials should be based on a combination of three technical approaches:

- increase the diversity of world supply of strategic metals through the development of promising deposits, both foreign and domestic, outside of southern Africa and the Soviet bloc and through exploration for new deposits of strategic materials;
- decrease demand for strategic metals through the implementation of improved manufacturing processes and recycling of strategic materials from scrap and waste; and
- identify and test substitute materials for current applications and develop new materials with reduced strategic material content for future applications,

There is a wide range of actions that the Government may draw from to implement some or all of these approaches. These actions vary in cost, degree of Government involvement, probability of success, and contribution to the overall strategy for reducing vulnerability. The actions include:

Collection and analysis of data and the dis*semination of* results *to* industry. Government already plays a key role in provision of essential information about strategic materials, An expanded role, including more emphasis on identification of foreign investment opportunities for U.S. firms abroad, sponsorship of a substitution information "bank," development of better data about domestic mineral occurrences, and periodic reexamination of trends in strategic materials recycling and conservation, would help Government policymakers adjust strategies to changing circumstances, and encourage private actions to reduce vulnerability,

Support for research and development and for mineral exploration. Implementation of any technical approach to reduce import vulnerability will assume a continuing R&D effort, most of which will continue to need Government support. Strategic materials R&D programs, decentralized among many agencies, need better coordination if common objectives, goals, and purposes are to be met.

Federal funding of strategic materials R&D in the areas of recycling, substitution, and advanced materials appears adequate to keep pace with the changing materials mix in the economy. In the area of mineral exploration, prospects for a major domestic discovery of one or more of these materials are not promising, but could possibly be enhanced through greater support of public and private exploration research, including basic research on geological theories of mineral occurrence, improved geophysical, geochemical, and drilling equipment, and more intense study of the resource potential of Federal lands.

Assistance for education and training. Advanced materials, now in their infancy, hold promise of altering the mix of basic materials used in many applications now dependent on strategic materials. International competition for supremacy in these emerging markets is strong, with some other countries, including Japan, placing greater emphasis than the United States on technical education and training of workers in these fields. Increased Government support to U.S. educational institutions in conjunction with the advanced materials industry may be needed to ensure the long-term competitiveness in these fields.

Development of alternative technologies and materials. In cases where the principal barrier to commercialization of a technology is the cost of demonstration and pre-commercial development, or where benefits arise from having the technology or material "on-the-shelf," the Government could support the construction and operation of demonstration plants or the testing and evaluation of substitute materials. This would reduce industry response time in an emergency,

Financial assistance for domestic industry. The economics of nearly all opportunities for domestic mineral development are discouraging to potential investors. If the benefits of domestic mineral production are desirable from the public's perspective, however, assistance could be provided in the form of subsidies, purchase commitments, loan guarantees, tax incentives or other Government financial aid. Such programs need not be limited to mineral production: processing of ores and metals, production of substitute materials, and operation of recycling facilities could also be encouraged by similar programs. Financial assistance programs could be expensive, however, so that their cost effectiveness, compared to other alternatives and to reliance on the free market, needs to be carefully considered.

Role of Government in reducing materials import vulnerability. The degree to which the Government should actively support activities to reduce materials import vulnerability ultimately depends on the perceptions of policymakers as to the degree of harm that could result from supply interruptions, the probability that such interruptions may occur, and the role policymakers see for the Government in dealings with the private sector. In addition, the effectiveness of the technical approaches that Government chooses to pursue depends, to some degree, on its commitment to their success and to the coordination of the approaches in a unified strategy directed toward reducing materials import vulnerability. The effectiveness of Federal policies also depends on establishing goals for strategic materials policy, identifying the most promising technical approaches to reduce vulnerability for priority materials, coordinating governmental actions, and encouraging industrial and academic activities in support of the technical approaches. In view of the multiplicity of Government activities that already affect the strategic materials issue and the long time required to implement most of the technical approaches, the Government would need a process for the periodic reevaluation of strategic materials objectives and of the effectiveness of programs implementing the technical approaches.

The following sections summarize the background to strategic materials issues and the most promising technical approaches to reduce the vulnerability of the United States to interruptions of supplies of strategic materials.

Introduction

The United States is well endowed with many natural resources. Timber, coal, water, and agricultural resources are the envy of the rest of the world. The endowment is not complete, however. The United States is dependent on foreign suppliers for many mineral resources. The Soviet Union and the nations of southern Africa are suppliers of many of the minerals and metals that the United States must import. Although in some cases these nations play only a limited role in the world supply of raw materials, for some materials they quite literally dominate the market.

Mine production of cobalt, chromium, manganese, and platinum group metals, all essential to defense and to the civilian economy, is concentrated in the Soviet Union and southern Africa (see map on pp. 8-9 for the worldwide distribution of mine production of these metals), Reliance on a potential adversary such as the Soviet Union for materials essential to defense and industry is an obvious area for concern. Nor is it certain that supplies from nations in southern Africa will continue without interruption: the division of nations on racial grounds, the role of Soviet influence and Cuban military involvement, the internal political division of key mineral-producing countries, and the vulnerability of mines and transportation systems to sabotage and guerrilla actions combine to raise questions about the reliability of mineral supplies, regardless of the good intentions or financial needs of the governments in power.

Dependence of the United States on a few nations of uncertain reliability for materials that are essential to many industrial and defense uses has heightened concern over materials and minerals policy in recent years. This concern is not new; since World War II U.S. policy makers have sought ways to reduce U.S. vulnerability to interruptions of supplies of strategic materials.

The most visible policy taken by the United States to guard against disruptions of supplies of strategic materials is the National Defense Stockpile (see box A). The objective of the stockpile is to support U.S. defense, industrial, and essential civilian requirements during a prolonged military conflict or declared national emergency, If properly stocked and maintained, the stockpile can be effective in coping with a disruption of supplies during a war or extended military conflict.

However, the defense stockpile does not protect, nor is it meant to protect, American industrial and other civilian consumers from

Box A.-The Strategic Materials Stockpile

For over four decades, the strategic and critical materials stockpile has been seen as a kind of insurance policy for safeguarding the United States against the effects of a supply emergency. The stockpile, however, is only intended to safeguard military, industrial, and essential civilian needs in times of war or declared national emergency, and is not a general-purpose source in an emergency.

First established in 1939, the stockpile was built up rapidly in the post-World War II and Korean War era, when the goal of the stockpile was to accumulate a 5-year supply of critical materials. Many of the materials now in the stockpile date from this period, and maybe antiquated due to changes in material specifications. During the Vietnam War period, substantial amounts of stockpiled material were declared excess to stockpile needs and sold by successive administrations—a circumstance that led to charges that the stockpile was being used to keep metal prices stable during the Vietnam War. (Stockpile goals had been reduced from the initial 5 years to 3 years in 1958, and to 1 year in *1972,* before being raised back to 3 years during the Ford Administration.)

In 1979, Congress reaffirmed its commitment to stockpiling through enactment of the Strategic and Critical Material Stockpiling Revision Act (Public Law 96-41). The law stated that the stockpile "should be sufficient to sustain the United States for a period of not less than 3 years in the event of a national emergency. . . " and "is to serve the interest of national defense only and is not to be used for economic or budgetary purposes." The 1979 law also established a stockpile transaction fund, under which materials can be purchased for the stockpile from sales of excess materials. At the time the law was passed, stockpile inventories in excess of the 3-year requirement were valued at *$4.9* billion. Acquisition needs were estimated to be $12.9 billion. In March 1981, President Reagan announced a major new stockpile acquisition program, aimed at meeting stockpile goals for 15 priority materials. For fiscal year 1985, the Administration is seeking to sell $78 million in excess materials and to purchase $120 million for the stockpile. However, the request is significantly below the amount required to meet stockpile goals. At present spending rates, it would take 100 years to meet stockpile goals.

The Federal Emergency Management Agency (FEMA) oversees the stockpile, and submits to Congress the Annual Materials Plan (AMP) for the buying and selling of materials for the stockpile. An AMP steering committee, comprised of 12 agencies and chaired by FEMA, develops the annual plan. Actual management of the stockpile sites, which are dispersed throughout the United States, is conducted by the General Services Administration.

Alternatives to acquisition and sale of stockpile materials are under consideration, including the potential for technology to upgrade stockpiled materials to today's standards. For example, most of the cobalt in the stockpile does not meet current industry requirements, and therefore may need replacement. The American Society of Metals, in a recent report to FEMA, suggested that U.S. firms be given stockpile samples to demonstrate whether the out-of-date materials could be processed to meet current standards. If so, some materials already in the stockpile could be readied for use in an emergency, and some materials may not need to be replaced through purchase.

Barter is an alternative means of obtaining materials for the stockpile. The U.S. Government operated a barter program under the Department of Agriculture from 1950 to 1973, which disposed of surplus agricultural commodities and acquired strategic materials for the stockpile. The total value of agricultural exports under this program was $6.65 billion. The barter program was suspended in 1973 when agricultural surpluses were drawn down, and stockpile goals were changed. In 1981, the U.S. Government again became involved in barter on a limited basis when it concluded three Jamaica bauxite-dairy barter agreements worth $47 million, but a formal barter program has not been reestablished. Approximately 20 barter bills have been introduced in the 98th Congress. The Administration has established a working group on barter to review proposals on a case-by-case basis.

Table A.— Domestic Consumption and Production of Strategic Metals

	Apparent consumption[a]	Domestic production primary	Domestic production scrap	Price	
Chromium:		(tons x 1,000)		$/M.T.[b]	
1979	586	0	67	54-58	
1980	567	0	72	54-58	
1981	533	0	70	51-55	
1982	333	0	63	48-52	
1983	334	0	78	48-52	
Cobalt:		(pounds x 1,000)		$/pound	
1979	18,806	0	1,170	24.58	
1980	17,054	0	1,183	25.00	
1981	12,532	0	972	19.73	
1982	11,452	0	871	12.90	
1983	15,712	0	724	12,50	
Manganese:		(tons x 1,000)		$/LTU[c]	
1979	1,250	31	0	1,40	
1980	1,029	23	0	1.70	
1981	1,027	24	0	1.72	
1982	672	4	0	1,58	
1983	730	4	0	NA	
Platinum group metals:		(troy oz x 1,000)		$/troy ounce Platinum	Palladium
1979	2,992	9	309	352	113
1980	2,846	3	331	439	214
1981	2,445	7	392	475	130
1982	1,822	9	344	475	110
1983	2,464	9	287	475	130

[a]Apparent consumption equals total imports minus exports plus domestic production plus increases of stocks and Inventories
[b]Chromium price is for metric tonnes of Transvaal ore. fob South Africa
[c]LTU (long ton unit) is the metal content of one long ton of one percent grade ore It is equivalent to 224 pounds of contained metal
NA—not available

SOURCE US Department of the Interior, Bureau of Mines

supply disruptions that result from economic or foreign political disturbances. The concentration of supply of important minerals in a few countries, combined with anxieties aroused by the success of the oil producers' cartel in the 1970s, has led to calls for materials policies that protect the Nation against supply disruptions in a wider range of scenarios than those contemplated under Defense Stockpile policies.

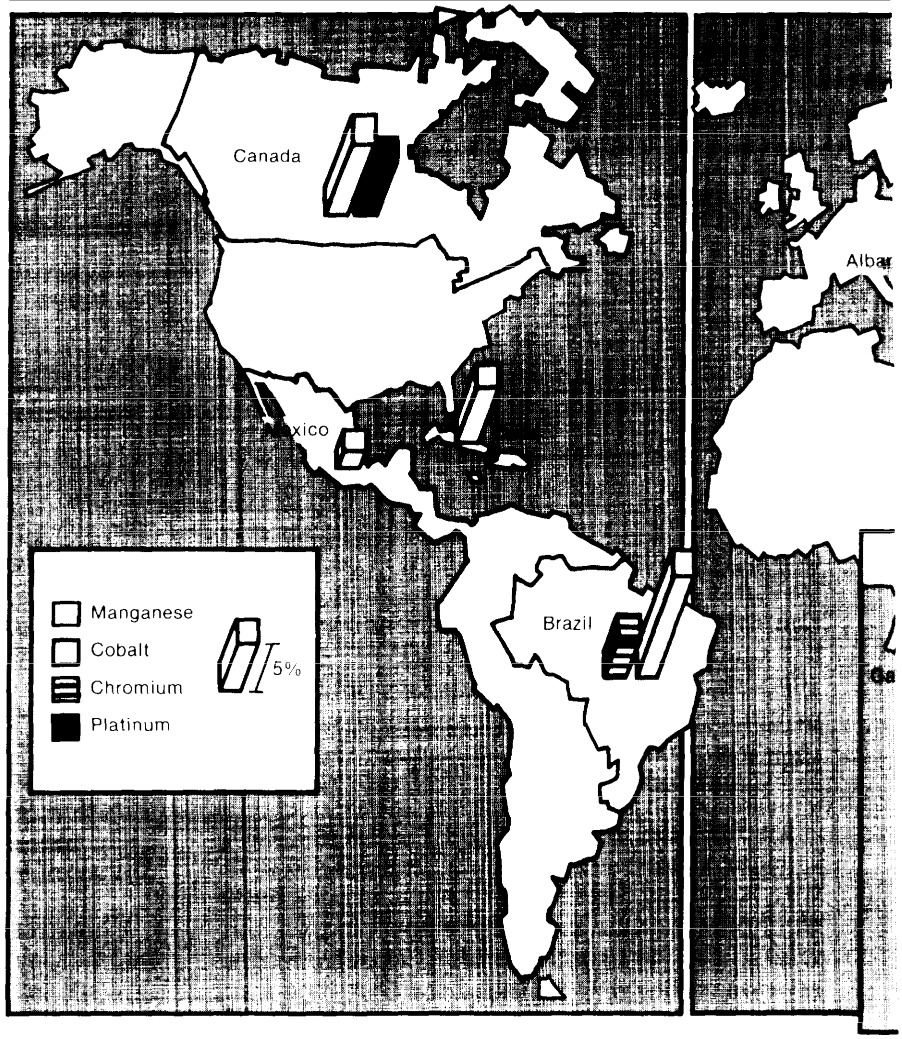
Two general approaches have been proposed to reduce materials import vulnerability in nonwar scenarios. One is to establish uneconomic stockpile, similar to the defense stockpile, but which maybe used in times of economic disruption rather than military conflict. The purpose of such a stockpile would be to reduce the impacts to the U.S. economy from peacetime market and supply disruptions. However, there is considerable skepticism on the part of industry that an economic stockpile could be managed without causing market disruptions itself. The advantages and disadvantages of various types of economic stockpiles have been the subject of much study. (See, e.g., OTA's, *An Assessment of Alternative Economic Stockpiling Policies, OTA-M-36,* August 1976.)

The second approach is technological. Through a combination of technical advances in mineral production, conservation, and materials substitution, the requirements for imported strategic materials can be lessened and the reliability of supplies can be increased.

This assessment concentrates on the role of technology in reducing the vulnerability of the United States to interruptions of supply of strategic materials. The technical approaches may be directed either toward developing alternative sources of supply and alternative technologies for use in cases of supply interruption or, in the longer term, toward developing new materials and processes that significantly re-

Distribution of Mine Production of Cobalt, Ch

Canada		**Finland**		**Turkey**		**Philippines**	
Cobalt	8%	Chromium	4%	Chromium	6%	Chromium	5%
PGM	6%	Cobalt	3%	**China**		Cobalt	4%
Cuba		**USSR**		Manganese	6%	**Australia**	
Cobalt	6%	Chromium	33%	**India**		Cobalt	5%
Mexico		Cobalt	8%	Chromium	3%	Manganese	8%
Manganese	2%	Manganese	32%	Manganese	6%		
Brazil		PGM	49%				
Chromium	4%	**Albania**					
Manganese	11%	Chromium	5%				



SOURCE Office of Technology Assessment, from U S Bureau of Mines data

m, Manganese and Platinum Group Metals—1981

Zaire	
Cobalt	47%
Gabon	
Manganese	9%
Botswana	
Cobalt	1%
Zambia	
Cobalt	15%
South Africa	
Chromium	34%
Manganese	23%
PGM	44%
Zimbabwe	
Chromium	5%

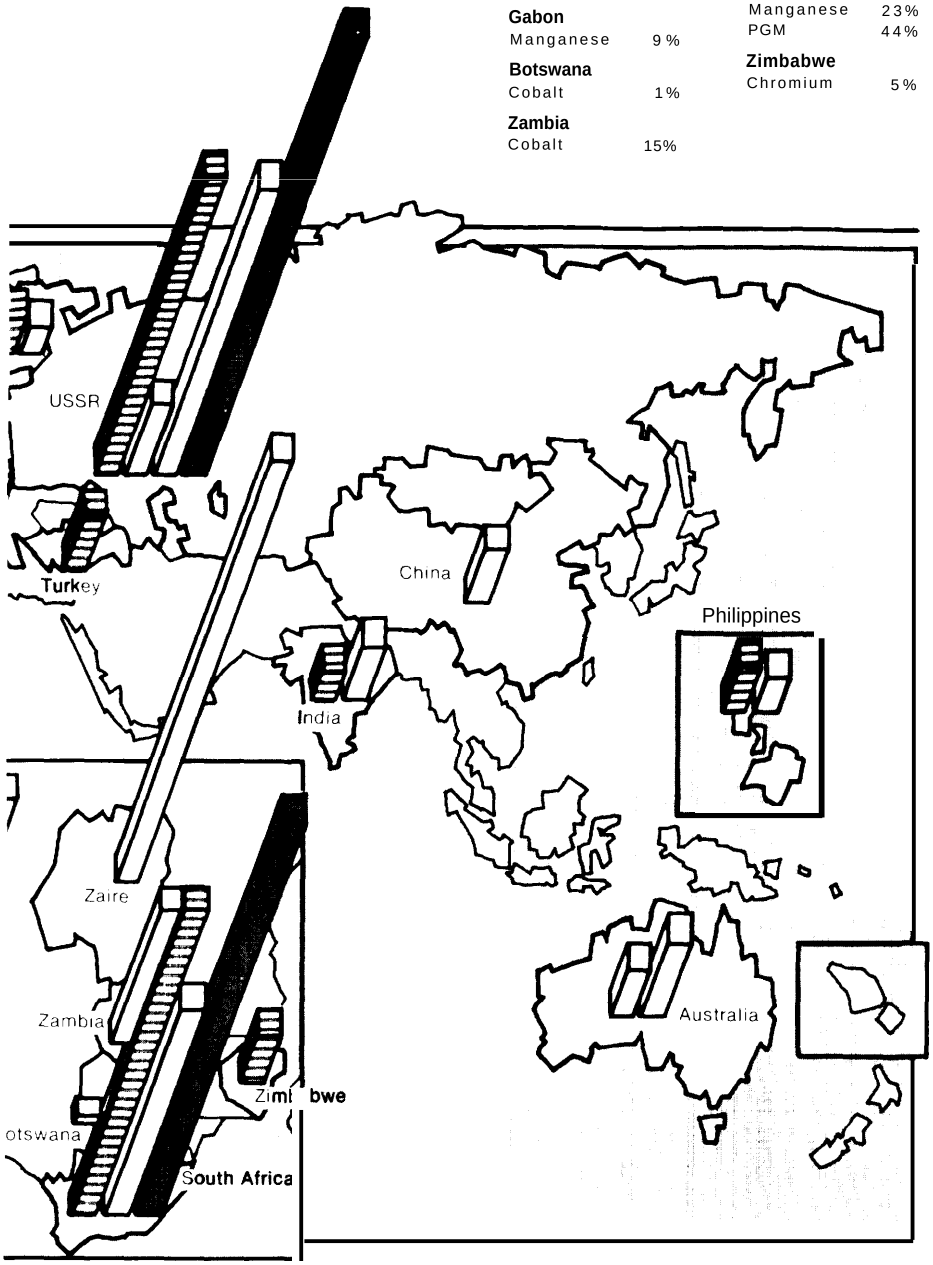


Table B.—U.S. mports of Strategic Materials—1982[a]

Source	Chromium Amount (st. tons)	Chromium Value ($ × 1,000)	Cobalt Amount (th. pounds)	Cobalt Value ($ × 1,000)	Manganese Amount (st. tons)	Manganese Value ($ × 1,000)	Platinum group metals Amount (troy ozs.)	Platinum group metals Value ($ × 1,000)	Total value of imports ($ × 1,000)
Albania	1.360	299	—			—			299
Australia	—	—	169	1.305	23.601	4 6·7	4.766	1.567	7.519
Belgium/Luxembourg	—	—	613	6.402			07.017	23.121	29.523
Botswana	—	—	364	2.817					2.817
Brazil	9 219	6.932	—	—	26.569	9.197	—	—	16.129
Canada	311	240	1 483	14.404	15.975	5.822	95.326	¹8.774	39.240
China	3 613	2.672	—	—	—			—	2.672
Finland	9 520	2.206	798	10.423	—	—	5.988	2.182	14.811
France	—	—	336	3.202	80.729	35.710		—	38.912
Gabon	—	—	—	—	23.156	3.514	—	—	3.514
West Germany	2.622	3.926	255	3.082	1.031	691	30.863	6 595	14.294
India	—	—	—	—	7.204	2.646		—	2.646
Italy	346	607	—	—	—	—	27.719	6.855	7.462
Japan	165	347	.024	8 77	4.564	3.334	3.546	1.383	13.835
Madagascar	12.920	2.683	—	—	—			—	2.683
Mexico	—	—	—	—	28.892	14.21·	162.311	5.645	19.856
Netherlands	—	—	28	659	—		27.336	3.916	4.575
Norway	55	110	852	9 053	907	965	26.874	6.033	16.161
Pakistan	1 360	330	—	—	—			—	330
Philippines	5 652	5.830	—	—					5.830
Portugal	—	—	—	—	14.966	5.20·		—	5.201
South Africa	1'3 473	40.996	266	.127	246.584	78.438	194. 64	355.356	475.917
Sweden	3 045	4.954						—	4.954
Turkey	12 649	4.947						—	4.947
United Kingdom	15	22	271	2.109	12.585	4.245	338.562	68.572	74.948
U.S.S.R.	8.840	1.629					405.043	37.733	39.362
Yugoslavia	0.153	8.144	—	—	2.998	.063	—	—	9.207
Zaire			4.972	68.704	—	—			68.704
Zambia	—	—	.164	11.323	—	—	—	—	11.323
Zimbabwe	21.576	0 290	—	—	—			—	20.290
Other	—		276	4.033	4.996	968	63.791	16.025	21.026
Total	226.894	°7 64	2 8 °	47.414	494.757	170.652	2.493.706	53.757	978.987

[a]Amounts and Total Value depressed in ≡82 because of the recession Total value of imports was $1 6 billion in 1981 and significantly over $1 billion in 1983 although precise figures have not yet been published for that year

SOURCE U S Department of the Interior B-reau of duce the need for strategic materials, The various technological approaches identified are distinct from, but may be combined with, the nontechnical alternatives, that is, continuation of the current policy of supporting the defense stockpile and, potentially, the establishment of an economic stockpile.

Identification of Strategic Resources

What makes a material strategic? Two factors must be considered: the critical nature of its uses and the vulnerability of its supply. The criticality of a material is measured by its degree of use in applications essential to the United States, both civilian and military. Vulnerability is assessed on the basis of the risk that the supply of the material may be interrupted, and the scale and duration of the potential interruption. Thus, a strategic material may be briefly defined as follows:

> A strategic material is one for which the quantity required for essential civilian and military uses exceeds the reasonably secure domestic and foreign supplies, and for which acceptable substitutes are not available within a reasonable period of time.

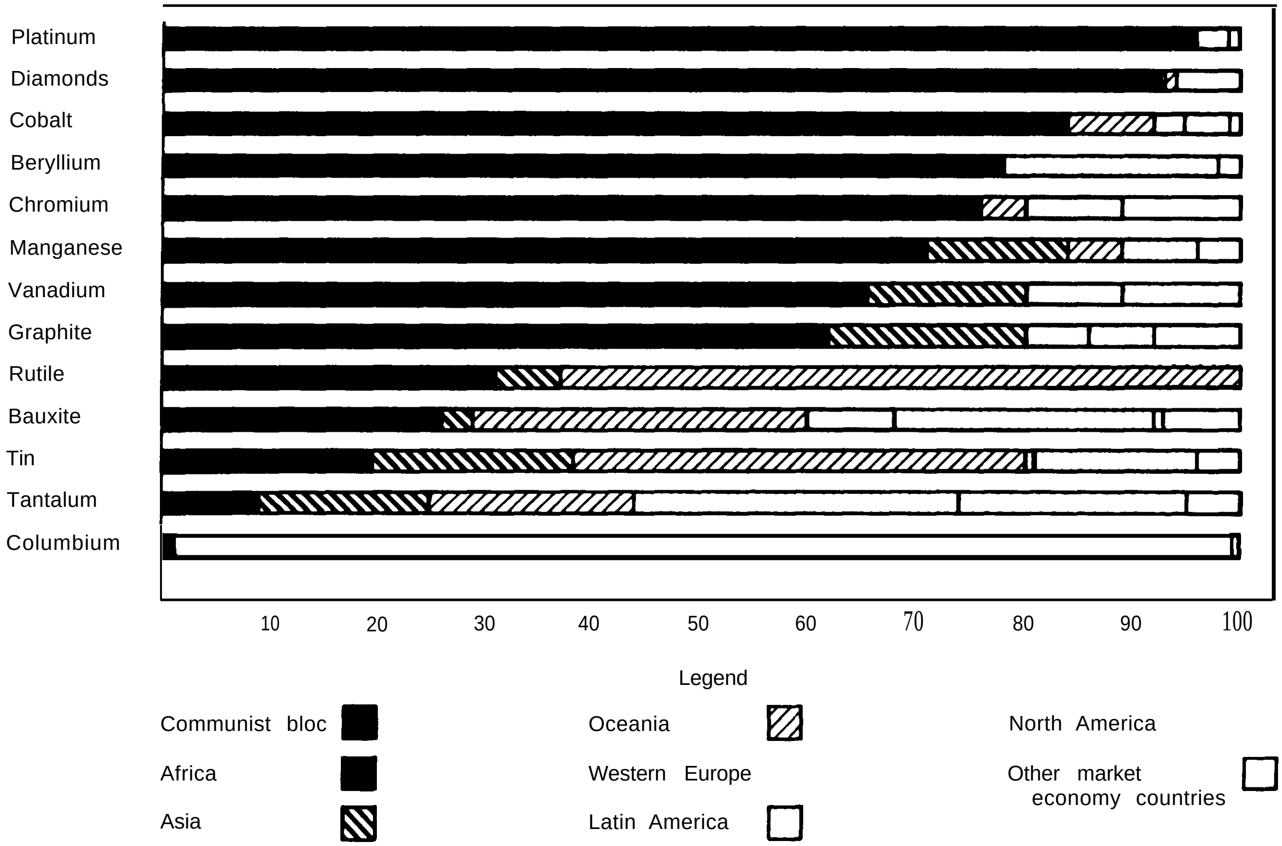
Because many materials are essential in some applications but not others, difficulties may arise in defining a material as critical. Definition of vulnerability poses still more difficulties, since the assessment of the risk of supply interruption involves a subjective analysis of the behavior of other nations. Altogether, the definition of a "strategic material," combining uncertainties both of criticality and of vulnerability is not a cut-and-dried matter.

The U.S. Bureau of Mines compiles and reports data on 86 important non-fuel mineral commodities. After eliminating the materials and minerals that the United States exports or for which the United States has no net imports and the minerals for which the United States relies on Canada for its supply, 33 commodities remain. This list can be reduced further by eliminating the materials which have a high degree of geographical and political diversity in their production.

The result is a list of 13 minerals and materials that are essential to the national economy and whose supply is relatively limited and vulnerable to interruption. The regional distribution of the production of these 13 strategic materials is shown in figure 1-1. For six of the materials in the figure, beryllium, chromium, cobalt, industrial diamonds, manganese, and platinum group metals, over 70 percent of world production is located in Africa or the Communist bloc. The pervasive role of chromium, cobalt, manganese, and platinum in the economy, as contrasted to the more limited roles for beryllium and industrial diamonds, place these four materials in a "first tier" of strategic materials; the remaining nine, while all essential to the U.S. economy, form a second tier of strategic materials.

The four first-tier strategic materials are the subject of this report, Chromium, cobalt, manganese, and platinum group metals are clearly essential to the United States, and their uninterrupted supply is certainly open *to* question. Issues considered with regard to these materials, and the technologies that may help reduce U.S. vulnerability to disruptions in their supply, will also have some application to materials in the second tier.

Figure 1-1 .—Regional Distribution of Strategic Material Production



SOURCE Off Ice of Technology Assessment from U S Bureau of Mines data

Essential Uses of Strategic Materials

The first-tier strategic materials have many uses, a number of which are considered to be essential. The essential uses of the first-tier strategic materials are discussed below.

Chromium

Chromium is used in a variety of applications throughout the economy, the most essential of which are superalloys, stainless steel, and as an alloying element in tool, spring, and bearing steels.

As an alloying element, chromium raises the hardness of steel, increases its strength and oxidation resistance at elevated temperatures, and increases its wear resistance. These properties make chromium alloy steel essential in springs, bearings, and tools, as well as in components of automobile engines.

In stainless steel, the formation of a tenacious chromium oxide film on the surface of the material provides a barrier to corrosion and oxidation. This corrosion and oxidation resistance is essential in chemical processing plants, oil and gas production, power generation, and in automobile exhaust systems, principally in the catalytic converter.

Chromium is combined with nickel, cobalt, aluminum, and titanium to give superalloy their exceptional corrosion and oxidation resistance at temperatures above the useful range of steel. For example, superalloys are used in the high-temperature regions of the aircraft gas turbine engine in parts such as turbine blades and vanes, turbine disks, and combustor liners.

Chromium in its mineral form of chromite is used in insulating liners in boiler fireboxes, steel and ferroalloy furnaces and vessels, and in foundry sands used for casting molds. In a chemical form it is used in pigments, metal treatments, leather tanning, and a variety of other applications. Although some of these uses are essential, the quantity of chromium required to meet them is small relative to the amount consumed in metallurgical applications,

Cobalt

Although U.S. demand for cobalt is less than 2 percent (by tonnage) of that for chromium, it is essential in many of its applications. The most critical are as an additive in some superalloy, as a binder for tungsten carbide tool bits, and as a constituent of some magnetic alloys. It is also desirable, but not irreplaceable, as an alloying element in some tool steels, hard facing alloys, and high-strength steels. Cobalt is contained in catalysts used in certain essential steps in the refining of petroleum and the manufacturing of chemicals. Other nonmetallurgical applications include pigments and paint dryers, but only a very small portion of these applications are essential.

Manganese

Although manganese is used in a variety of applications, ranging from an alloying agent in aluminum alloys and bronzes to nonmetallurgical uses in batteries and chemicals, its principal use—about 90 percent—is as an alloying and processing agent in steel. As an alloying element, manganese prevents the formation of iron sulfides which adversely affect the properties of steel. In addition, manganese is the most cost-effective method of increasing the hardness of steel, leading to its use in certain impact-resistant steels and in the high-strength low alloy (HSLA) steels. As a processing agent in steelmaking, manganese is instrumental in removing oxygen from steel and in improving slag characteristics.

Platinum Group Metals

Platinum group metals (PGMs), which comprise platinum, palladium, rhodium, iridium, osmium, and ruthenium, are essential in catalytic applications in petroleum refining, chemical processing, and automotive exhaust treatment. They are also used as contacts in telecommunication switching systems and as electrodes in ceramic capacitors, but in many of these applications gold is a satisfactory, albeit expensive, substitute for some of the platinum group metals. Other applications include jewelry and medical and dental equipment.

Outlook for the Future

Domestic production of stainless and alloy steel accounted for 237,000 tons of chromium in 1981. Requirements for these steels are projected to grow substantially for the rest of the century. Superalloy, which require high purity chromium metal or low carbon ferrochromium, accounted for less than 7,000 tons of chromium in 1981. Demand for chromium in this application may nearly double by the year 2000.

Domestic cobalt consumption was 5,800 tons in 1981. Superalloys, the largest consumer, accounted for 2,100 tons or 36 percent of domestic consumption. Magnetic alloys used about 800 tons (14 percent of domestic consumption); chemical and petroleum catalysts accounted for about 600 tons (10 percent of domestic consumption); and cemented carbide tools and dies consumed about 500 tons (almost 9 percent of domestic consumption). Growth of cobalt demand is expected to be slow over the next decade, increasing somewhat after 1995.

In 1981, 775,000 tons of manganese contained in ore and ferroalloys were used in the production of carbon, stainless and alloy steel. If current steelmaking practices continue, manganese requirements for the domestic production of steel would be expected to rise significantly. However, changes in steelmaking practices could result in a significant decrease in the amount of manganese required per unit of steel production, causing a major drop in future manganese consumption per ton of steel (see p. 27).

U.S. demand for platinum group metals was 1,92 million troy ounces in 1981. Of this total, 607,000 troy ounces, or 32 percent, were used in catalytic converters of automobiles. Other catalytic uses in the chemical and petroleum industries accounted for 342,000 troy ounces (18 percent of domestic consumption). Electrical applications accounted for almost 500,000 troy ounces (26 percent of domestic consumption).

PGM demand for catalytic converters may more than double by 1995 as automobile sales increase and as larger vehicles, such as heavy trucks and buses, are required to use converters. Demand for PGMs in the petroleum industry will probably grow at roughly the same rate as the economy, unless there is a sharp increase in demand for domestic fuels that would require large quantities of PGM catalysts in the expansion of refinery capacity. Growth of demand for PGM catalysts in the chemical industry is difficult to predict. Increased demand for "specialty" chemicals (e. g., pharmaceuticals, agricultural pesticides and herbicides, and biocatalyst) could push PGM consumption in the chemical industry to as much as 400,000 troy ounces in 1990 and to over 800,000 troy ounces by 2000, PGM demand in the electrical industry is likely to increase slowly, although a sharp increase in palladium demand for ceramic capacitors is likely in the near future and demand for this use will remain high for several years until high prices and tight supplies encourage the use of substitute materials in this application.

These projections must be taken with caution. They are based on extensions of current patterns and trends, and do not fully reflect the effects of advances in materials production technology, nor do they reflect technical advances in end uses that may result in significant increases or decreases in consumption of these materials, However, the projections do provide a starting point for the evaluation of the importance of the various technical alternatives to materials import reliance that are discussed below.

Production of Strategic Materials

Chromium is found in many parts of the world, but world mine production is dominated by several large, high-grade deposits. In 1982, South Africa accounted for 27 percent of the total world chromium production of about 2.6 million short tons. The Soviet Union produced 36 percent of the world total; six other countries, Albania, Brazil, Finland, the Philippines, Turkey, and Zimbabwe, each accounted for between about 3.6 and 6 percent of world production.

In 1982, the United States imported 227,000 short tons of chromium contained in ore and metal. About half of the imports were as chromite ore: 59 percent from South Africa, 6 percent from the Soviet Union, 11 percent from the Philippines, and the rest from a variety of sources. The rest of chromium imports were ferrochromium and chromium metal, with 35 percent coming from South Africa, 26 percent from Zimbabwe, 12 percent from Yugoslavia (produced, in part, from Albanian chromite), and the balance from diverse sources,

In 1982, Zaire produced 45 percent of the world supply of cobalt, while neighboring Zambia produced 13 percent, The Soviet Union and Cuba together produced 15 percent of the world's cobalt, Canada accounted for 6 percent and Australia 8.7 percent, with lesser amounts being produced in Finland, Morocco, the

Philippines, New Caledonia, and Botswana. Principal suppliers to the United States were Zaire, 36 percent of imports; Zambia, 8.5 percent; Canada, Norway, Finland, and Japan between 6 and 11 percent each; and Belgium/Luxembourg, 4.5 percent, Belgian cobalt originated from ore obtained from Zaire, while Australia, Canada, and the Philippines supplied cobalt ore to other processes,

Manganese ore supplies are more diversified among major producers than are supplies of chromium or cobalt. The Soviet Union accounted for 41 percent of 1982 world production and South Africa accounted for 23 percent. Australia, Brazil, Gabon, India, and China each accounted for between 5 and 7.1 percent. U.S. imports of ore came from Gabon (19 percent), South Africa (55 percent), Australia (16 percent), and Brazil (3 percent). Manganese was also imported as ferromanganese, with South Africa providing 40 percent and France providing 21 percent.

Production of platinum group metals is concentrated in the Soviet Union and in South Africa, accounting for 54 percent and 40 percent of 1982 world production, respectively. U.S. imports were from South Africa (48 percent), the Soviet Union (16 percent), and the United Kingdom (14 percent, processed from material imported into the United Kingdom from South Africa and Canada).

Historical Perspective

In the past 25 years, the United States has had at least four major disruptions in the supply of materials critical to the economy and the national defense. The first of these occurred in 1949 when, in a Cold War exchange of trade restrictions with the United States, the Soviet Union stopped the export of manganese and chromium ore to the United States. The second interruption was the U.S. boycott of chromium from Rhodesia (now Zimbabwe). The third was a many month hiatus in the import of nickel from Canada as workers carried on a prolonged strike, Most recently, political disturbances in Zaire, while not actually reducing cobalt production, triggered major disruptions in supplies, inventories, and prices for cobalt.

The Soviet Union embargo on chromium and manganese exports to the United States in 1949 was a political action. It was a response to a U.S. clampdown on exports of machinery, tools, trucks, and scientific equipment to the Soviet Union—which, in turn, was a response to the Soviet blockade of Berlin in 1948. Another politically motivated supply cutoff was the embargo on imports of Rhodesian chromium from 1966 to the end of 1971. The U.S. embargo conformed with a United Nations resolution which called on all members to refrain from trade with Rhodesia after it declared independence from Great Britain and set a course of continued white minority rule.

In neither of these cases were there serious effects on the economy or any interruption of defense production. The response in both instances was, essentially, to find other foreign sources of supply. After the 1949 Soviet embargo, the U.S. Government was active in finding alternative suppliers and in upgrading the infrastructure of these suppliers by providing steel to improve India's rail transport system, sending railcars to South Africa, and helping to improve rail and port equipment in Ghana.

With the U.S. embargo on purchases of Rhodesian chromium in *1966,* the Government sold excess chromium from the national stockpile but otherwise took little active part, leaving industry to find alternate suppliers, That industry was able to do so quite readily with little evidence of shortage was due to several factors, besides the stockpile sales. The Soviets promptly volunteered to serve as alternate suppliers of chromium to the United States, even though the United States was fighting against their allies in Vietnam. Prices rose, drawing other suppliers like Turkey and the Philippines into increased production, And the Rhodesian embargo leaked. Despite the international embargo, France, Japan, and Switzerland bought what was probably Rhodesian chromium from South Africa and Mozambique, Had they not done so, the alternate suppliers might have been hard put to provide the whole industrialized world with chromium.

A most important factor in reducing the economic impact of the loss of Rhodesian chromium was the wide-scale adoption of the argon-oxygen decarburization process for the manufacture of stainless steel, This process made it possible to use high-carbon ferrochromium made from South African chromite in place of the more costly low-carbon ferrochromium made from Rhodesian ore that had been used before the embargo.

The 1969 nickel strike in Canada shut down supplies from the quintessentially "safe" foreign source. Unlike the politically inspired embargoes described above, it caused actual shortages and acute price hikes. The reasons for the acute effects were twofold: the cutoff occurred at a time of strong demand for nickel when world supplies had already been tight for 3 years; and Canada was then almost the sole supplier to the United States. Even so, military and essential civilian production continued without interruption throughout the shortage. By 1970, world nickel prices were back to normal and supplies were ample.

The shortages and high prices elicited changes in the behavior of U.S. nickel users, They substituted other materials where they could, for example, replacing nickel stainless steel with chrome-manganese stainless steel (a substitute alloy that had been developed during the Korean war). Many users turned to nickel recycled from scrap. And they paid high prices for the limited remaining supplies of nickel—once more supplied largely by the Soviets, An important factor in recovering from the acute nickel shortage was the U.S. Government's release of a large quantity of nickel from the stockpile as the strike came to its end. Earlier Government actions had been to allocate available supplies to military users.

During the cobalt "shortage" of 1978-79, there was never any real interruption of supply, On the contrary, production in Zaire and Zambia—by far the largest cobalt producers in the world market—rose 43 percent during 1978 and another 12 percent in 1979. But the combination of rapidly rising world demand and fears of a supply cutoff, triggered by a rebel invasion of Zaire's mining region, set off a wave of panic buying. This, coupled with the recent removal of an important source of world supply (sales from the U.S. stockpile) and the relatively low industry inventories of cobalt, sent cobalt prices soaring.

During the "shortage," cobalt users turned quickly to substitutions and recycling. Under the spur of high prices, nonessential uses made way for essential. Government allocation was not needed to reserve cobalt for superalloys for military jet engines; superalloy producers and users paid the high prices demanded by dealers, and they recycled. Use of cobalt in permanent magnets for loudspeakers dropped by half as ceramic magnets were substituted. The ceramic magnet technology was already on the shelf but had not been widely adopted because it required redesign and retooling. High cobalt prices made these changes worthwhile, The drop in demand for cobalt due to substitution, recycling and conservation had its effect on prices, which turned down in 1980. By 1982, with worldwide recession, cobalt prices plunged below the 1978 level.

None of these cases resulted in severe or long-lasting damage to the United States. Nonetheless, the issue of foreign dependence for materials critical to the country is a major one. For some materials, alternative suppliers are by no means as readily available today as they were in past years. In 1949, small producers such as India and Turkey were capable of expanding their production sufficiently to replace our major suppliers of manganese and chromium; they are not today, Nor are there any major new technologies in stainless steelmaking opening up new types of ore for exploitation, as the argon-oxygen decarburization process did for South African chrome ore after Rhodesian supplies were embargoed. The Canadian nickel strike and, to a lesser degree, the disruption in cobalt markets resulting from the Zairian disturbances, showed that interruptions in metal supplies could have financial effects much greater than might have been expected, on the basis of the dollar value of imports of these metals,

These four diverse historical examples illustrate two important points. First, interruptions or even complete cessation of supply from major producers of strategic materials are possible, whether as a result of international politics, internal rebellion, labor difficulties or other causes. Second, technology provided a means to respond to interruptions of supply in each of the examples. Thus, a basic question to be answered in considering the full range of possible elements in a Government policy for strategic materials is the extent to which technology can protect the U.S. economy from the adverse effects of possible interruptions in the future. The first step toward answering this question is to identify the technological alternatives to the current state of reliance on imports of strategic materials.

Technological Approaches to Reduce Materials Import Vulnerability

There are many technological approaches to reduce U.S. materials import vulnerability, and they may be combined in many different ways. For the strategic materials policy maker, it may be best to group these various approaches into a materials technology triad. The components of this triad are minerals production and metal processing, conservation, and substitution.

The production leg of the triad includes domestic production, diversified foreign production, and production of minerals from regions beyond national jurisdiction, The processing of these minerals into forms used by industry, particularly ferrochromium and ferromanganese for the steel industry, is also included in the production leg. The conservation leg includes improved manufacturing technologies that use materials more efficiently, such as improved casting methods, more efficient forging techniques, and the manufacture of parts from powdered metals. It also includes the recycling of scrap generated during the manufacture of components and of obsolete scrap retrieved from discarded products. The third leg of the triad, substitution, involves the use of materials with reduced strategic materials content in place of traditional materials. An example is the use of 9 percent chromium steel in place of stainless steel containing 18 percent chromium in certain powerplant applications. Substitution also includes the displacement of strategic materials by new materials such as advanced ceramics or composites.

Individually, no one technological approach can meet all of the varied problems that might arise with regard to the security of supply of the four first-tier strategic materials; the approaches must be combined to improve their effectiveness. Further, each provides opportunities that differ for the various materials. Thus, the most effective combination of technological approaches for dealing with materials import vulnerability varies from one material to the next,

Summary of Technological Approaches

In reviewing the outlook for technological approaches to reduce materials import vulnerability for the four first-tier strategic materials, several points become apparent. First, there is no single solution. For example, as is shown in table 1-1, substitution is extremely important to reducing chromium vulnerability, but has little contribution to make in the case of manganese. Recycling, which is important for

Table 1-1.—Summary of Most Promising Technological Approaches to the Reduction of Strategic Materials Import Vulnerability

Approach	Potential benefits[a]	Barriers to implementation
Chromium:		
Substitution	Direct substitution could now reduce U.S. chromium needs by one-third. Another one-third reduction may possibly be achieved through a 10-year R&D program.	Low cost of chromium alloys deters use of substitutes; lack of information on substitutes slows their use in times of shortage; need for further tests and experience limits near-term potential for substitution to one-third of consumption.
	Advanced materials may displace chromium alloys in certain aerospace and industrial applications.	Basic and applied research is needed to improve properties and reliability of advanced materials. Designers and engineers need better understanding of properties and limitations of advanced materials. Tests and standards need to be developed for these materials.
Conservation	Expanded recycling of scrap and waste could provide at least 20,000 tons of chromium beyond current recycling levels.	Barriers to chromium recycling are economic, not technical.
Production	Development of alternative foreign sources could provide about 30,000 to 60,000 tons, about 10 to 20% of current U.S. demand.	At current prices for chromium, there is no economic incentive to diversify suppliers. Government assistance would be required to make development of alternative suppliers more attractive.
Cobalt:		
Conservation	Recycling could recover much of the cobalt in scrap and waste that is currently lost or downgraded.	Principal barrier is economic; however, extensive recovery of superalloy scrap may require use of technology that is now limited to laboratory testing.
	Process improvements now being adopted may make significant reductions in the amount of cobalt used to make jet engine components.	Economic factors favor the adoption of process improvements.
Substitution	Direct substitutes under development could reduce the need for cobalt by 50°/0 or more in some critical superalloy applications.	Industry has little or no incentive to expend the time and money needed to qualify alternative alloys except when there are significant performance advantages.
	Advanced materials may displace cobalt in some aerospace and industrial applications.	Barriers to adoption of advanced materials to reduce cobalt consumption are the same as for chromium, as described above.
Production	Domestic production from three sites could produce up to ***8*** million pounds of cobalt per year.	Current prices for cobalt and/or co-product metals are too low to justify investment without Federal subsidies.
	New foreign production could provide almost 15 million pounds of cobalt per year.	Investments are being postponed until cobalt prices rise. Lead times of 2 to 5 years are needed to bring deposits into production,
Manganese:		
Conservation	Process improvements could reduce needs for imported manganese in steel by 45% by year 2000.	Adoption of improvements will depend on incremental upgrading of domestic steelmaking facilities.
Production	Alternative suppliers to South Africa and the Soviet Union could increase production after 2 to 3 years to expand facilities.	Assured market for increased production is needed to justify investment in production and transportation facilities: U.S. would be in competition with other consumers for new production; facilities for processing ore into ferromanganese must also be available.
Platinum group metals (PGMs):		
Conservation	Recycling of catalytic converters could recover 500,000 troy ounces of PGM annually by 1995.	No significant barriers; several years will be needed to develop collection and processing infrastructure.
Product ion	Development of the Stillwater deposit could produce 175,000 troy ounces of PGM in the near term; additional development is possible.	Domestic production will require slightly higher prices for platinum and palladium and evidence of increased demand.

[a]The benefits accruing from the various approaches are not cumulative. For example, as scrap generation in manufacturing is reduced through improved processing techniques, the potential benefits of recycling are also reduced

SOURCE Office of Technology Assessment

platinum and cobalt, is also a minor contributor for manganese, Similarly, processing efficiency, diversity of supply, and domestic production all vary in importance for each of the strategic materials.

Second, none of the approaches offers a "quick fix" to import vulnerability problems, All require a continuing commitment, whether the approach is to maintain substitution information on a current basis, or to move new materials from the laboratory to industrial use, or to encourage investment in new mines or processing facilities.

Third, the existence of technological alternatives is based on a history of long and continued support by Government, academia, and industry for basic research in materials science and engineering. Had this commitment been significantly less, fewer alternatives would be available today.

Fourth, in only a few instances is it likely that the technological approaches which offer promise to reduce import vulnerability will be implemented under normal economic and market conditions. Improvements in steelmaking technology and recycling of catalytic converters are underway and are likely to continue, as are improvements in superalloy fabrication technology. Development of the Stillwater, MT, PGM deposit is a strong possibility, although the actual decision to go ahead will rest on a positive assessment of future markets for platinum group metals. Development of advanced materials that contain no strategic materials is likely, but it is not clear how useful these materials will be in applications that now require strategic materials, For the rest of the technical approaches, the outlook for implementation is poor unless new incentives are forthcoming, provided either by the market (in the form of tightened supplies and higher prices) or by the Government (as investment assistance or price supports).

Chromium

PRODUCTION

World production of chromite, the ore from which chromium is obtained, is largely accounted for by southern African and Communist countries. In 1982, South Africa accounted for 22 percent of chromite production, the U.S.S.R. accounted for 24 percent, Albania for 12 percent and Zimbabwe for 4 percent. Another 22 percent was spread among Brazil, Finland, India, Madagascar, the Philippines, and Turkey. The processes of ferrochromium, the form used in making alloy and stainless steel, are more diversified. In the 1980-82 period, the Soviet Union and South Africa each accounted for 20 to 25 percent of world production. Japan was a midlevel producer, accounting for about 15 percent and the United States accounted for about 7 percent. These figures are static, however, and do not reflect the trend toward decreased diversity of ferrochromium production. From 1974 to 1980, U.S. ferrochromium production declined by 29 percent, Japan by 21 percent, and France by 30 percent. During the same period, South African ferrochromium production rose by 193 percent and the Soviet Union 279 percent.

Domestic Production.—Domestic resources offer few opportunities for reducing import dependence for chromium. United States chromium resources are limited to low-grade deposits, such as the Stillwater Complex in Montana, the small, discrete deposits of chromite in northern California and Oregon, and extremely low-grade chromite associated with nickel laterites such as the Gasquet Mountain deposit in northern California. The Stillwater deposit was mined under Government contract during World War II, but it is not under consideration for development now, Somewhat lower in cost to mine than the Stillwater ores, the disseminated, or podiform, chromite deposits of California and Oregon also provide a resource that could be tapped in times of national emergency, but one that is not competitive with worldwide chromite deposits now in operation,

Only one domestic chromite resource, the Gasquet Mountain nickel laterite deposit, is under consideration for development at this time. The development proposals call for this deposit to produce nickel and cobalt, with a chromite concentrate as a byproduct. Considering current prices for nickel and cobalt, the outlook for this mine is dim. Even if it does enter into operation, the production of chromite would be less than 3 percent of U.S. annual consumption of chromium.

Although only low-grade deposits of chromium have been discovered in the United States, the possibility remains that better deposits exist. High-grade chromite deposits, where they exist, are normally associated with the Precambrian rock such as that which underlies much of North America. Unfortunately, only small areas of this rock are exposed. Conventional mineral reconnaissance techniques, which rely heavily on the identification of surface features associated with the desired mineral deposits, are limited to these exposed areas. In other areas, the precambrian rock is covered by thick layers of sediment or glacial debris, precluding the use of surface features to disclose the nature of subsurface deposits. Advances in exploration technology, however, may improve the outlook for the discovery of more deposits. Improved geophysical techniques, such as arial gravimetric and magnetic analyses targeted specifically at chromium, could reduce the dependence of explorationists on surface geology. Improved geochemical and core drilling technology could encourage the exploration for chromium (and other minerals) by reducing exploration costs. In the long term, improved scientific understanding of the processes that form deposits could assist explorers to identify regions in which to concentrate their efforts.

Diversified Foreign Production.— Unless major new deposits of chromite are discovered, the opportunities to diversify supplies of chromium are limited to minor expansion of small producers, such as Albania, Turkey, and the Philippines, and the exploitation of known, but undeveloped, chromite resources in the laterites and beach sands of New Caledonia and the Philippines,

The deposits in Albania, Turkey, and the Philippines are small and discrete, and it is likely that many deposits remain undiscovered, Production from these countries might be increased if techniques for identifying scattered deposits of chromite can be improved.

Technologies have been developed for the production of chromite from nickel laterites and beach sands, but the ore grades of such deposits generally range from 2 to 5 percent chromic oxide. With the major producers supplying ore that contains 35 to 48 percent chromic oxide, the lateritic and sand deposits would require substantial concentration to produce a marketable product, and the estimated cost of producing such a product is two to three times the current market price.

Ferrochromium Processing Capacity.—Before 1970, the United States had sufficient capacity to meet its needs for ferrochromium, the form of chromium used in the production of steel. Since that time, however, imports of ferrochromium have reduced the domestic industry's share of United States demand and, with time, the capacity to produce ferrochromium domestically is also decreasing as furnaces and plants are decommissioned. As domestic processing capacity declines, the United States loses its flexibility to turn to alternative sources of ore from countries that do not have their own ferrochromium facilities.

The decline of the domestic industry is directly related to the cost of operation. Costs of power, labor, and transportation are, in general, lower for the producers in countries where chromium ore is mined than for U.S. firms, In addition, national policies in the producer countries often provide economic incentives for local processing of ferroalloys.

The advantages enjoyed by producing countries are not insurmountable. The growing need to blend together ores that have different chemical and physical properties means that all producers will need to import ores, so that all producers will pay the additional cost of transporting ore rather than the more concentrated ferroalloy. Labor rates in many producer countries are now quite low, but are likely to increase more rapidly than in the United States, thereby narrowing the cost differences. Improvements in the technology for measurement and automatic control of processing operations should provide gradual improvements in domestic plants. In the longer term, advanced furnaces may provide means to reduce energy consumption, further reducing advantages held by some foreign producers. Economic and trade agreements may also help narrow the economic gap. With the advantage of proximity to consumers, which gives U.S. producers an advantage in responding to special orders placed by the steel industry, technical improvements in ferroalloy facilities could improve the potential to maintain a domestic ferrochromium industry capable of processing ore from a variety of foreign sources,

In the long term, with wise adoption and application of technology, the industry may be able to keep a significant share of the domestic market for ferrochromium, ferromanganese, and other ferroalloys. In the near term, however, there is little technology can do; so, during this period, the domestic industry is likely to need economic and political assistance if it is to preserve a market presence against foreign competition.

CONSERVATION

Chromium-bearing manufacturing and obsolete scrap are marketable products that account for about 10 to 15 percent of U.S. consumption of chromium, Because recycling of manufacturing scrap is already at a high level, there is little opportunity to increase chromium recovery in this area. There are, however, significant opportunities to increase the recovery of chromium from obsolete stainless steel scrap and from waste produced by steelmaking and chemical processing plants.

Recycling of obsolete stainless steel scrap is difficult because of the long lifetime of stainless steel products, the wide dispersion of the products through the economy, and the difficulty of separating the stainless steel from other materials in discarded products. The most promising prospect is in the automotive area. About one-third of all obsolete stainless steel scrap is obtained from junked automobiles; even so, only 30 to 40 percent of the chromium contained in the cars is recovered. The best opportunity for increasing chromium recovery from automobiles lies in the catalytic converter. The shell of the converter, which is made from Type 409 stainless steel, contains 1,8 to 2.6 pounds of chromium—over half of the total chromium content of the automobile. Since this type of stainless steel is magnetic, it is not easily separated from other magnetic parts either before or after the cars are shredded. However, interest in recycling of the platinum in the converters is increasing (see "Platinum Group Metals" below) and the converters are starting to be removed for separate processing, which makes the stainless steel shell available for recycling. If recycled separately, the converter shells could produce about 5,000 to 7,000 tons of chromium per year, or up to 3 percent of the 1981 U.S. demand for chromium in stainless and alloy steels,

Opportunities for recovery of chromium from industrial wastes are difficult to quantify because of a lack of up-to-date information. In 1974, the most recent year in which data were compiled, chromium lost in industrial waste was estimated to be over 28,000 tons, including over 17,000 tons from various metallurgical processes. Since that time, several firms have instituted both internal and commercial waste processing programs. For example, Inmetco, a subsidiary of Inco, processes flue dust, mill scale, and grinding swarf containing 3,100 tons of chromium with chromium recovery rates of about 90 percent. Other facilities have been developed to process other forms of scrap and waste.

Chemical and metal finishing industry wastes were estimated to contain over 3,000 tons of chromium in 1974, which was then almost entirely lost. Although recycling or regenerating the chromium from these wastes is expensive, the cost of meeting strict standards for the disposal of waste in landfills could encourage the recovery of metals, Furthermore, the value of the metal could help lower the costs of processing the waste for disposal. Several recovery technologies, including closed-loop systems to extend the life of acid baths, have been under development and hold promise to reduce chromium losses in the future.

SUBSTITUTION

Direct Substitutes.—The most important use of chromium is in metallurgical applications, where it provides properties of hardness, wear resistance, high-temperature strength, and resistance to oxidation and corrosion. It is in these uses that substitution offers the greatest opportunities to reduce the requirements for imported chromium.

Because of its relatively low cost, availability, history of satisfactory performance, and familiarity to designers, chromium-containing steels, particularly stainless steels, are widely used, even in applications that do not require the superior performance provided by the high chromium content. There are many opportunities to use materials with reduced chromium or no chromium at all, but there is no single substitute material that can serve in all of the applications where stainless steel is now used. Appropriate substitute materials must be selected for specific applications. Some of the more promising substitutes for stainless steel are summarized in table 1-2.

It is important to note that there are few incentives to replace stainless steel in most applications. As a result, most potential substitute materials remain at the laboratory stage because, without economic incentives to adopt alternative materials, private industry will not spend the money required to move the materials to commercial use.

Advanced Materials.—In the long term, nonmetallic and unconventional metallic materials may provide alternatives to chromium-bearing stainless and alloy steels and superalloys. Ceramics are being developed for possible use in engine components, power plants, and bearings—all applications that now use stainless or alloy steel—and in gas turbine engines in place of superalloys. Advanced composites may be used in applications that require high strength and light weight. New metallic materials, including rapidly solidified metals and long-range ordered intermetallics may provide alternative materials for use at high-temperature applications, such as turbine components in jet engines, that otherwise require alloys with chromium contents of 20 percent or more.

However, advanced materials must overcome substantial barriers before they can significantly reduce the need for chromium or other strategic materials, With few exceptions, these materials are still in early stages of development. Considerably more work must be done in the laboratory to improve the properties of the materials, and processing and manufacturing methods must be developed to accommodate their special properties. Even then, the materials must gain acceptance by designers, who will evaluate them not only on eco-

Table 1-2.—Substitution for Chromium in Metallurgical Applications

Application material	Current material	Alternative	Developer	Status
Boiler tubes in conventional and nuclear powerplants	Type 304 stainless steel (18% chromium)	Modified 9°/0 chromium/1% molybdenum steel	Oak Ridge National Laboratory	In process of certification by ASME code committees
General use in moderately corrosive or oxidizing environments	Type 304 stainless steel	Manganese-aluminum steels	Diverse locations in U.S. and other countries	Laboratory stage in U.S. Minor practical applications in China
High-temperature oxidizing environments	Type 304 stainless steel	8°/0 aluminum/6% molybdenum steel	Bureau of Mines	Laboratory stage
Corrosive environments (chemical processing)	Type 304 stainless steel	9°/0 chromium alloy steel	Bureau of Mines/Inco	Laboratory stage
General use (moderate corrosion and oxidation uses)	Type 304 stainless steel	12°/0 chromium stainless steel	NASA Lewis Research Center	Laboratory stage
Automotive exhaust systems and catalytic converters	Type 409 stainless steel (1 2°/0 chromium)	6-12°/0 chromium alloy steel	ARMCO	Laboratory stage

SOURCE Office of Technology Assessment.

nomic grounds but on the familiarity that grows with practical experience,

Cobalt

PRODUCTION

Cobalt is generally produced as a byproduct of nickel or copper mining, its sales supplementing the revenues from these other products. Only rarely is it mined for its own sake. The largest cobalt producers, Zaire and Zambia, produce cobalt from their copper mines. Canada and Botswana produce it from nickel-copper mines, and Cuba and the Philippines recover it from nickel laterites. Less commonly, cobalt may also be found in deposits of lead, iron, and manganese. Only in Morocco has cobalt been produced as a principal product. As a result of the wide distribution of cobalt-bearing ores, diversified production, both domestic and foreign, is a more promising option for the reduction of import vulnerability for cobalt than for chromium, manganese, or platinum group metals.

Domestic.—In the aftermath of the Korean war, the United States obtained cobalt from domestic sources, largely by granting Federal subsidies to the mine operators. Three deposits, the Blackbird mine in Idaho (a copper-cobalt mine), the Madison mine in Missouri (lead-cobalt) and the now-depleted Cornwall mine in Pennsylvania (an iron deposit with small amounts of cobalt), provided the bulk of domestic cobalt. In addition to these proven deposits, several other deposits are known and have been studied as possible domestic sources. These are the copper-nickel deposits of the Duluth Gabbro in Minnesota and the cobalt-containing nickel laterites in northern California.

At current and projected prices for cobalt and other metals that can be produced from the Blackbird mine, the Madison mine, the Duluth Gabbro, and the nickel laterite deposit at Gasquet Mountain in California, domestic cobalt production is economically unattractive, Unless prices for cobalt, nickel, lead, and copper show major and prolonged increases, private industry will not develop any of these deposits. Increases on the order of 50 percent for nickel and copper, or 100 percent or more for cobalt would be necessary to encourage private investment. At these higher prices, domestic production of cobalt could be significant, Development plans for the Blackbird mine call for the production of 3.7 million pounds of cobalt per year, for the Madison mine 2 million pounds, and for the Gasquet Mountain deposit 2 million pounds. The lives of these mines vary from 10 to 20 years, based on proven reserves. Potential cobalt production of hypothetical mines in the Duluth Gabbro is estimated to be from 1 million to 2 million pounds annually,

Diversified Foreign Production.--The high market prices that are required for domestic production of cobalt have led developers to look for deposits in foreign countries that offer more attractive economics. With long-term price increases less extensive than those required to make U.S. deposits economic, cobalt production from nickel mines in Canada and Australia, which accounted for 10 percent of world production in 1980, can be increased substantially.

Increases in cobalt and nickel prices would also improve the prospects for the development of cobalt deposits in Indonesia, New Guinea, New Caledonia, and Peru. These four deposits are summarized in table 1-3. The total potential cobalt production of these four deposits could be 14.7 million pounds per year if they were all to enter production. As with the domestic deposits of cobalt, however, these four are unlikely to be developed under current economic conditions. In fact, development at Gag Island was recently halted due to poor economic outlook and partnership disagreements,

Table 1-3.—Potential New Foreign Cobalt Production

Site	Estimated production (million pounds/year)	Leadtime to start production
Gag Island, Indonesia	2 8	2 *to* 3 years
Ramu River, New Guinea	5 9	5 + years
Goro, New Caledonia	20	3.5 to 5 years
Marcona Mine, Peru	4.0	2 years
Total	147	

SOURCE Off Ice of Technology Assessment

and development of the other three deposits awaits improved markets for nickel and cobalt.

Ocean Resources.—For over 100 years it has been known that in the depths of the ocean there are deposits of nodules and crusts of manganese that contain copper, nickel, and cobalt, sometimes in concentrations that would be very attractive in land-based deposits. Advances in the technology for ocean resource exploration and development during the 1960s and 1970s raised the possibility of recovering these minerals from the seabed. Commercial interest centered on the manganese nodules of the east central Pacific ocean where the nickel, copper, and cobalt contents were at their highest. After a peak of interest in the late 1970s, however, interest in the development of these resources declined sharply, Although uncertainties about the legal right to mine the resources contributed to the decline in interest, more significant were the increases in the projected cost of exploitation (based on the analysis of data from prototype tests conducted in 1979 and 1980) and the realization that assumptions of future increases in the price of nickel and copper were overly optimistic, The high cost of building and operating an ocean mining system is compounded by the legal uncertainties arising from U.S. abstinence from the seabed mining provisions of the Law of the Sea Convention, and by the cost of development and testing remaining to be done on mining systems. With time, as higher grade land-based resources are depleted, the resources of the deep sea floor may well become a major source of cobalt and other metals. At this time, however, land-based sources of cobalt, whether foreign or domestic, appear more attractive for commercial development.

CONSERVATION

There are a number of conservation alternatives to reduce U.S. requirements for cobalt. The manufacture of superalloy components is a particularly attractive area for improvement. A considerable amount of machining is performed on jet engine components, resulting in large quantities of manufacturing scrap. Ratios as high as 10 to 1 for purchased metal to metal used in the engine are seen, with ratios of 6 to 1 being common. Less than 50 percent of this superalloy manufacturing scrap is recycled for use in superalloy; the rest is used in steel for its nickel and chromium content, is exported to foreign consumers, or is disposed of as waste. Obsolete parts made of superalloys are contaminated with carbon and sulfur, and generally are not recycled for production of jet engine components. Past failure to utilize scrap has been based, in part, on engine manufacturers' standards that limited the use of scrap and, in some cases, prohibited its use altogether, due to concern that contaminants would not be removed in refining processes and the resulting alloy would be unsuitable for use in critical applications, With experience, it has been possible for manufacturers to relax the specifications to allow the use of superalloy that contain up to 50 percent recycled materials (principally from manufacturing scrap) in aircraft applications,

Recent advances in remelting and refining technology have led to the development of processes that could refine manufacturing scrap, and even some obsolete scrap, to produce new alloys that can meet the strictest of standards required by aircraft engine manufacturers, Processes have also been developed to recover individual elements from mixed alloy scrap. The usefulness of these processes is limited, however, because they have only been tested in the laboratory or in small pilot plants. Further time and effort are needed to determine their technical and commercial feasibility as full-scale facilities.

A second conservation measure that could reduce import vulnerability for cobalt is the use of more efficient manufacturing technologies, Particularly important among these, for superalloy, are near-net-shape technologies, These include powder metallurgy, in which powdered metals are pressed under high pressure and temperature into a form close to the final shape of the desired component; hot isothermal forging, in which materials are deformed under extremely plastic or superplastic conditions to near final shape; and advanced precision casting methods that allow the production of complex shapes as a single part, eliminating many machining steps that would otherwise produce scrap, much of which would be downgraded or lost.

An example of the benefits of these advanced manufacturing processes is the production of the turbine disk for the Pratt & Whitney F-100 jet engine. When first designed, this 15-pound part was forged from a 250-pound billet of Astroloy (17 percent cobalt), which resulted in 235 pounds of chips containing 40 pounds of cobalt. With isothermal forging, the billet weight is reduced to 126 pounds and the material used is IN-100 (18.5 percent cobalt) instead of Astroloy; the result is 110 pounds of chips containing 20.5 pounds of cobalt—almost a 50 percent saving in cobalt. Future improvements are expected to reduce chip formation to 35 pounds of material containing less than 7 percent cobalt; the result will be a net cobalt savings of over 80 percent, compared with the original manufacturing process,

Improvements both in recycling and in manufacturing efficiency act to reduce U.S. dependence on imports. However, the economic factors that may impel manufacturers to adopt them are different. Manufacturing improvements are likely to continue because the improvements result in overall cost savings and performance benefits, not because they reduce cobalt consumption, per se. Advances in recycling technology are much more dependent on a specific interest in conserving cobalt; they are likely to occur slowly, if at all, unless price increases or supply uncertainties provide incentives for further development in the reuse of superalloy scrap for critical applications,

SUBSTITUTION

Owing largely to the uncertainty of cobalt supplies following the 1978-79 disturbances in Zaire, the U.S. Government sponsored research into the potential to reduce strategic material requirements in jet aircraft, Results of laboratory tests indicate that cobalt content of some superalloys currently used in aircraft engines could be reduced by 50 percent or more through the use of new alloys, Some steps along this line were taken by jet engine manufacturers through the substitution of nickel-based superalloy containing little or no cobalt for cobalt-based superalloys and cobalt nickel-based superalloys with high cobalt content. Further steps along these lines are more difficult, however, The certification of a new alloy for use in critical aircraft applications is an expensive and time-consuming process, one that companies will not carry out unless the substitute provides clear performance benefits or unless faced with high metals prices or extreme and prolonged uncertainty about the availability of cobalt.

As with chromium, long-term opportunities to develop substitutes for cobalt-bearing alloys are enhanced by the development of advanced materials, Ceramic cutting tools are already being used in place of high-temperature tool steels or cemented carbide tool bits that contain cobalt. Ceramics and carbon-carbon composites have shown some potential for high-temperature applications that now require superalloy. Advanced metallic materials, including rapidly solidified materials and long-range ordered alloys, also have high-temperature characteristics that may lead to their future application in place of conventional cobalt and chromium-bearing superalloys.

Manganese

About half of the manganese consumed in the production of steel is contained in iron ore and scrap, Since these materials are available domestically or from Canada, this supply of manganese is relatively secure from interruption. The remainder of the manganese in steel is provided in the form of manganese ore and ferromanganese that the United States must import.

PRODUCTION

World manganese production is dominated by a limited number of very large deposits that, because of their large reserves and high manganese content, are very economical to operate. The major producers, South Africa, the U. S. S. R., Gabon, Australia, China, and Brazil, accounted for all but 5 percent of world production in 1982. In addition, Mexican produc-

38-844 0 - 85 - 2 : QL 3

tion accounted for 2 percent of total world production. Production is concentrated in the U.S.S.R. (4 I percent of 1982 production) and South Africa (23 percent).

Domestic Production.—The United States is endowed with only relatively small and low-grade deposits of manganese. Although these deposits were exploited during World War II, they are not economically competitive with the world class deposits now in production. Prices between $8 and $35 per long ton unit (equivalent to 22.4 pounds of manganese) are estimated to be required for domestic deposits to become economic. With the current market price ranging between $1.45 and $1.75 per long ton unit, it is doubtful that domestic manganese will be developed, although some production of low-grade ferruginous manganese ores (defined as ores containing less than 35 percent manganese) is possible.

Undiscovered deposits of manganese of commercial or near-commercial grade may exist in the United States. However, manganese cannot be detected by airborne methods, so exploration must be conducted on the ground, raising the cost of initial reconnaissance. Wide distribution of manganese in rock and soil makes it difficult to distinguish traces of manganese associated with ore deposits from the general background concentration, reducing the usefulness of geochemical exploration methods. If exploration for manganese is to be encouraged, improved theories of formation must be developed so that promising locations for deposits can be identified and geochemical and geophysical methods can be concentrated in these more promising areas. Given the availability of manganese at low cost from a variety of suppliers, it is unlikely that private firms will conduct research aimed at locating domestic manganese deposits since the benefits, if any, would occur far in the future.

Diversified Foreign Production.—Increased production of manganese at the Groote Eylant mine in Australia offers the best opportunity for diversification away from South Africa. High-grade ore and proximity to ocean transport make expansion of this deposit relatively easy. Mexico also could expand its production, but Mexican ore is lower in quality than that of the major producers. Expansion of this deposit would be more costly than expansion of the Australian deposit because, in addition to the cost of expanding mine capacity, additional investment to increase the capacity of the ore upgrading equipment would be necessary. Possibilities for diversification are also limited in Gabon, where a long transportation line that includes an aerial tramway limits the potential to increase the production rate, In Brazil and China, a large share of manganese production is dedicated to the current and future needs of their domestic steel industries. Although expansion of manganese production for export is possible in these countries, it is not currently planned,

Ocean Production.—Certain areas of the ocean are favorable to the formation of crusts or nodules containing up to 30 percent manganese. Manganese contained in these deposits is finely disseminated through the material and not easily processed into a conventional manganese ore. With further development of ocean mining technology, the nodules located on the Blake Plateau off the coast of Florida could become a new domestic source of manganese but costs of production would be similar to those of other domestic ores and much higher than many foreign ores. Similarly, manganese could be recovered as a byproduct of deep ocean mining in the Pacific for nodules rich in nickel, copper, and cobalt. However, mining of the Pacific nodules appears to be far in the future.

Manganese Processing Capacity .-For its largest and most important application—as a processing and alloying agent in the manufacture of steel—manganese ore must be processed into ferromanganese. As is the case with chromium, the United States has become dependent on foreign processing of manganese ore to meet much of its demand for ferromanganese. Since the equipment and processes for ferromanganese production are similar to those for ferrochromium (in fact, the facilities are sometimes converted from one product to the other, although at a reduction in efficiency), the technical approaches to maintain a domestic processing capacity are also similar. Technological advances offer little help to the domestic industry in the immediate future. However, improved technology for monitoring and controlling ferromanganese furnaces could raise the productivity of domestic facilities to a limited degree. Over a longer period, the development, refinement, and adoption of new high-voltage and plasma arc furnaces may give domestic producers an edge in efficiency over foreign producers who do not adopt the technology and allow them to be competitive with those who do.

CONSERVATION

Improvements in steel production technology provide the best prospect for the reduction of manganese import vulnerability. Careful measurement of sulfur levels and manganese additions, resulting in manganese contents near the lower level allowed by steel specifications, can result in reductions of manganese consumption per ton of steel by about 8 percent. External desulfurization, which reduces manganese requirements, may provide even more dramatic savings and so may up-to-date steelmaking techniques such as continuous casting, which keep to a minimum internal, or "home" scrap that in each cycle through the steelmaking process contributes to inevitable losses of manganese in slag.

As shown in table 1-4, 35.6 pounds of manganese are used on average to produce one ton of steel, 17.8 pounds of which is provided by imported manganese ore and ferromanganese. Only 13.8 pounds remain in the steel while the other 21.8 pounds is lost in slag, dust, and waste. By the year 2000, the average manganese content of steel is likely to decline slightly to 12.2 pounds per ton of product, but major reductions are expected in the amount of manganese lost. The net result will be a reduction in total manganese consumption per ton steel from 35.6 to 24.8 pounds. Even more striking, and more important from a security of supply viewpoint, the consumption of imported manganese ore and ferromanganese is estimated to decline from 17.8 pounds per ton of steel to

Table 1.4.—Current and Projected Manganese Consumption in U.S. Steel Production (pounds of manganese per ton of steel product)

	Current (1981-82)	Projected–2000 Expected	Best	Worst
Inputs:				
Manganese products:				
Manganese ore	1 9	1,2	1,0	1.5
Ferromanganese	159	8.3	5 5	1 2 2
Total	17.8	9 5	6,5	13,7
Iron and steel products:				
Iron ore and sinter	129	8.5	7.1	10.1
Purchased ferrous scrap	5.0	6.8	6.9	66
Total	17,9	15.3	14,0	167
outputs:				
Retained in steel products	13,8	122	112	134
Losses (slag, dust, waste)	21,8	126	9.4	170
Total manganese use	35,6	248	20,6	304

SOURCE Office of Technology Assessment

9.5 pounds per ton, a decline of over 45 percent from current levels.

SUBSTITUTION

The bulk of manganese consumption is in steelmaking, and in this application there is no satisfactory alternative, with the exception of the use of rare earths in a limited group of applications that can justify the sharply higher cost,

Platinum Group Metals

PRODUCTION

The Soviet Union and South Africa account for over 90 percent of world PGM production, with most of the remainder coming from Canada. Production in all other countries accounts for only 1 percent of world production. Canadian production results from byproduct recovery from copper-nickel ores and cannot be expanded substantially without corresponding increases in the production of these metals. Since economics do not favor increases in copper or nickel production, Canada cannot be considered an important diversification opportunity.

The United States offers the only significant opportunity to affect, even slightly, the dominating role of South Africa and the U.S.S.R. in PGM production. While minor amounts of PGM are obtained as a byproduct from three U.S. copper mines and, in the past, from placer deposits such as Goodnews Bay, AK, there are plans under consideration to develop resources of platinum group metals in the Stillwater Complex in Montana. This deposit could produce 175,000 troy ounces of platinum group metals annually, or between 2 and 3 percent of current world production. This operation is under evaluation and review, and the decision to go ahead with development will rest on assumptions of stable or increasing metal prices,

Undiscovered domestic deposits of platinum group metals are almost certain to exist, most likely as placer deposits such as Goodnews Bay and as byproducts of copper-nickel sulfides, Although less likely, another major domestic PGM deposit, similar to the Stillwater Complex, could exist, Exploration for such a deposit would face problems similar to those described for chromium and for cobalt-bearing copper-nickel sulfides. As with those metals, prospects for success in exploration for PGMs would be enhanced by improvements in geophysical, geochemical, and drilling technology and by advances in the understanding of the geologic processes that formed PGM deposits,

CONSERVATION

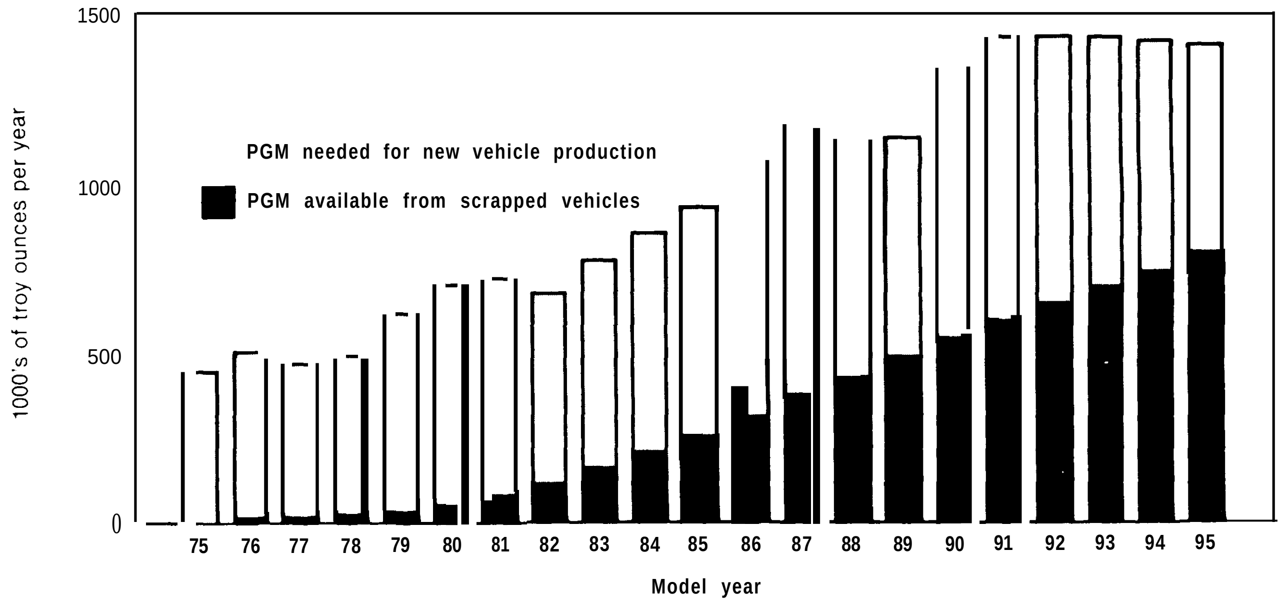
As with manganese, conservation technology provides the greatest opportunity for the reduction of materials import vulnerability in platinum group metals. Platinum contained in industrial catalysts is already extensively recycled, but the recovery of platinum group metals from electronic scrap and from obsolete automotive catalytic converters is less extensive. There are no major technological barriers to recovery of platinum group metals from either type of scrap. Instead, the principal barriers are in the collection of scrap from widely dispersed locations for processing at central facilities, Scrap from electronic manufacturing plants is the easiest to collect, and recycling operations are well underway in this area. Obsolete electronic components are also processed, but this is hampered by the high labor intensity required to identify and separate platinum-bearing components. Catalytic converters are now beginning to enter the scrap yards in sufficient quantities to interest platinum recyclers, and a number of firms are showing interest in processing the converters to recover the contained platinum group metals. Platinum metal available annually from catalytic converters, which was about 115,000 troy ounces in 1982, is projected to grow to over 800,000 ounces in 1995 (fig. 1-2), Actual recovery will probably not exceed 500,000 troy ounces, since only about 70 percent of obsolete cars and trucks reach automotive dismantles where converters may be removed for recycling, and some PGM is lost in processing.

It is also possible that new engine designs may allow the reduction of pollutants without the need for catalytic converters. However, the wide-scale adoption of any significantly new automotive engine is not likely until the next decade, and long-term prospects will depend on price and performance factors, not on potential savings of platinum group metals.

SUBSTITUTION

Substitution opportunities for platinum group metals are greatest for electronic components, Gold is a substitute for platinum in electric and communications relays, with substitution decisions being based on the relative prices of gold and platinum, Silver and palladium alloys may be used in place of pure platinum in many applications, although platinum may offer superior performance and reliability. Palladium, now used in ceramic capacitors in rapidly increasing amounts, may be subject to substitution in 5 to 10 years as technologies using silver, nickel, and lead electrodes are improved. In catalytic applications, however, the outlook for substitution is dim. Unless new developments arising from advances in the study of surface science and chemistry lead to new catalytic systems, the high efficiency and long lifetime of platinum catalysts make them virtually irreplaceable.

Figure 1-2.—PGM Demand vs. Potential Supply From Recycling



SOURCE Sierra Research

Implementation of Technological Approaches

There are many technological approaches to reducing import vulnerability for each of the four first-tier strategic materials. These are summarized in the preceding section. They vary in the potential contribution they could make to the reduction of vulnerability, in the cost of carrying them out, in the period of time when they are effective, and in the assurance that they will fulfill their potential. These factors, as well as the interrelationships among the approaches, mean that it is important to direct and coordinate the implementation of technology toward specific goals, As a result, the management of strategic materials policy is critical to the successful implementation of the various approaches. The following sections address alternatives available to the United States, both in the general management of materials policy, and in the implementation of the technologies.

Legislative Guidance for Strategic Materials Policy

The 1980 National Materials and Minerals Policy, Research and Development Act (Public Law 96-479] provides a basic policy framework that could be used to develop and evaluate various technological approaches for reducing U.S. import vulnerability. The law emphasizes the importance of research and development activities related to all stages of the materials cycle (from exploration and mineral extraction through recycling and disposal) in addressing materials problems, The law applies to all materials, not just those for which the United States is import dependent, but many of its provisions apply to strategic materials in particular,

The Critical Materials Act (Public Law 98-373) requires the Administration to establish a Critical Materials Council, reporting to the Executive Office of the President. The Council is required, among other things, to prepare a critical materials report and assessment, to be reviewed and updated on a biennial basis, and also to prepare a Federal program plan for advanced materials, to be annually reviewed. The Council is also to review annual authorization and budget requests related to Federal material activities, so as to ensure close coordination of goals and directions of such programs with Council policies.

In addition, several other laws, already in place, could be employed should Congress wish to encourage private industry to adopt technical alternatives to reduce import vulnerability. Title III of the Defense Production Act (DPA) of 1950 authorizes direct Federal subsidies, purchase commitments, loan guarantees, and other instruments to assure availability of essential defense materials and industrial processing capabilities. The main use of Title III has been to encourage domestic production of strategic materials, especially during the Korean war and its aftermath, but DPA also could be used to encourage other private sector actions, such as development of processing technologies and substitute materials. Congress, in April 1984, authorized the appropriation of up to $100 million to the Department of Defense for Title III projects for fiscal years 1985 and 1986, and provided new criteria for Presidential review of proposed projects before they are undertaken. Other measures of potential relevance to implementation of these technical alternatives include Federal stockpiling law (comprehensively amended in 1979 as the Strategic and Critical Materials Stock Piling Revision Act), the Minerals Policy Act of 1970, and the Stevenson-Wydler Technology Innovation Act of 1980, which emphasized transfer of federally developed technological innovations to the private sector.

Structure and Information for Strategic Materials Policy

The 1980 materials act required the Executive Office of the President to assume a more active role in coordinating and formulating materials policy, beginning with preparation of a materials program plan to be submitted to Congress by the President on a one-time basis. The plan, submitted in April 1982, emphasized domestic production and stockpile issues. It did not encompass the full range of technological issues (including substitution and recycling) emphasized in the 1980 act.

In spite of strong statements of interest in strategic materials issues, the Administration has yet to carry out all of the provisions of the 1980 act. Specific reports required of the White House Office of Science and Technology Policy (OSTP) have not been submitted to Congress, and a Department of Defense report (due to Congress in late 1981) has not yet received Administration clearance. Although a policymaking structure, based in the Cabinet Council on Natural Resources and the Environment and the renewed Committee on Materials, was established by the Administration, there is strong evidence that materials policymaking procedures remain relatively uncoordinated, both among agencies and among technological approaches.

It was the goal of the 1980 act to require the coordination of agencies over the range of materials technologies. Since this goal has not been fulfilled, Congress may wish to consider further action to assure compliance, for example by establishing specific reporting dates for the OSTP and the Department of Defense, and by requiring submission of a revised program plan, with the explicit requirement that the plan include evaluation of the role of substitution and conservation technologies in U.S. strategic materials policy.

Another alternative to improve the coordination and direction of Federal strategic materials policy would be to require the Administration to prepare, on a regular basis, a multi-year strategic materials program plan that would establish long-term goals and objectives for materials policy, Such a plan could be submitted on a 4-year schedule, reflecting the long-term goals of each Administration,

Goals, Objectives, and Coordination of Federal Materials R&D

The Federal Government is the principal sponsor of research related to strategic materials. This research is conducted through many agencies in the Government, with the Departments of Defense, Energy, Interior, and Commerce and the National Aeronautics and Space Administration being major sponsors. In the past, this research has succeeded in developing many of the technological alternatives identified in this report. However, goals of this research are often narrowly directed towards problems of specific interest to the sponsoring agency.

Many of the technological approaches identified in this report will yield their benefits only in the medium to long term. To obtain these benefits, executive branch policies need to be clearly defined and stable over a number of years, Establishment of research priorities among materials, identification of specific objectives for Federal programs, and formulation of overall strategies may be needed so that individual agencies can better plan their research, development, and budget priorities.

Information developed so far in response to the 1980 materials act is insufficient to provide a basis for coordinated interagency responses to strategic material issues. A 1983 inventory of materials research conducted by the Committee on Materials (COMAT) did not disaggregate research funds by specific material or by research activity. Nor has COMAT required individual agencies to identify all strategic materials research within their own organizations.

Without more detailed information as to the level of research support, by agency, by type of research and by material, Federal objectives for strategic materials policy cannot be established in an effective manner. In order to strengthen the Federal mechanism for policy formulation, Congress may wish to provide additional guidance to the Administration for the review of Federal strategic materials R&D as required by the Critical Materials Act,

Mineral Production and Metal Processing

The current distribution of mineral production and metal processing facilities around the world is dictated largely by the economics of exploitation; although national policies to encourage mineral development, promote employment, gather foreign exchange, or protect the environment also affect the flow of investment. The limited number of high-grade deposits of the four first-tier strategic materials has resulted in a narrow range of producers, and policies of foreign governments to promote local economic interests are contributing to a declining role for domestic firms in the ferroalloy processing industry. Although the pressures of market economics and of the development policies of producer nations are strong, actions to expand the range of suppliers, both through diversity of foreign supplies and domestic production, can be taken. Four alternatives to broaden the range of suppliers and producers are discussed below. The opportunities for production of strategic metals from known domestic deposits are summarized in table 1-5.

Domestic Production of Strategic Materials

Reasonable prospects exist for domestic production of 5 to 10 percent of U.S. demand for platinum group metals. Opportunities for the development of domestic resources of other first-tier strategic materials are limited to several low-grade cobalt deposits. Industry evaluation of these deposits, located in Idaho, Missouri, and California, indicate that about 7.7 million pounds of cobalt could be produced annually over a 10- to 15-year period. However, at current market prices for cobalt (and for the nickel, copper, lead, and zinc also found in the various deposits) development of these resources in competition with the existing low-cost producers in Zaire and Zambia will not proceed. Further R&D on ore concentration and processing systems might improve the outlook for development somewhat, but the only means to ensure the development of these resources is through Government purchase contracts for metal produced from the mines. Production of cobalt from the Idaho and Missouri deposits would require long-term (10 years or more) commitments to purchase cobalt output at $16 to $25 per pound. With recent contracts

Table 1-5.—Outlook for Development of Known Domestic Deposits of Strategic Resources

	Chromium	Cobalt	Manganese	Platinum
Good News Bay, AK	—	—		1-2
Stillwater Complex, MT	3		—	1-2
Madison Mine, MO		2-3		
Blackbird Mine, ID		2-3		—
Gasquet Mountain, CA	2-3	2-3	-	
Duluth Gabbro, MN	—	3		3
Domestic Manganese	—	—	3	

–Not applicable
1— Economic at current prices
2 Marginally economic to subeconomic -under consideration for exploitation
3—Subeconomic—not considered for commercial exploitation at current metals prices

SOURCE Off Ice of Technology Assessment

for cobalt from Zaire running up to $12 per pound, the cost of subsidizing mine production of 2 million pounds of cobalt would run between $8 million to $26 million per year. For this cost, the United States would be assured of cobalt production amounting to 16 percent of 1981 domestic consumption,

According to industry estimates, development of the Gasquet Mountain deposit at current prices for nickel would require cobalt prices in the $20 to $25 per pound range. However, an increase in the price of nickel from the 1983 average of $2.20 to $3.50 per pound might make cobalt economic at about $12,50 per pound. However, such a dramatic increase in the price of nickel is unlikely.

Exploration for Domestic Resources

The fact that known domestic resources of strategic materials are very limited does not rule out the possibility that there may be significant deposits, as yet undiscovered. However, little domestic exploration for these minerals is going on, The reasons are the high cost of exploration, combined with industry pessimism about the likelihood of locating deposits of chromium, cobalt, or manganese that can be profitable in current and projected markets,

Several steps may be taken to increase the potential for discovery of domestic resources of the first-tier materials. The Government can provide economic incentives, principally through the tax system, to improve the economics of exploration. The cost of the incentives could be reduced by making them effective only for exploration that leads to the development of the target materials. However, tax incentives can only improve project economics by a marginal amount, so other action might be required if exploration for strategic materials is to be encouraged,

Targeting of Government mineral resource assessments toward the first-tier materials and increasing the detail of the assessments could identify areas of favorable potential for strategic materials. Government-supported research on improved geophysical and geochemical technologies could reduce the cost of prospecting and exploration for these materials. The lower costs, combined with improvements in techniques directed toward the desired materials, could increase private exploration for the first-tier materials.

Improved understanding of the geological processes that form deposits of strategic materials offers the greatest opportunity to expand domestic strategic materials resources. The benefits of increased research into the process of mineral formation and into techniques of predictive geology will only be seen in the long term, but, since many promising areas for the first-tier materials are covered by layers of glacial debris or sediment, predictive methods may be essential if the Nation's resource endowment is to be assessed.

Diversity of Foreign Supplies

The potential to diversify supply to reduce U.S. materials import vulnerability is greatest for cobalt and manganese. There are also opportunities to diversify somewhat the supply of chromium. Supply diversity, however, requires investment in and construction of new or expanded mining and transportation facilities. The distribution of world resources and the economic policies of producer countries have resulted in the current distribution of production, so policies meant to encourage diversity of supply must somehow change the economics of production in desired locations to attract investment.

A first step to diversity of suppliers is for the Government to identify and make known to private investors the most promising diversification opportunities. A basic program for this purpose is now underway in the International Development Cooperation Agency where the Trade and Development Program supplies funds for resource assessments of deposits of strategic materials, identifies potential U.S. participants in development activities, and brings the potential participants together with resource experts and officials in the foreign country.

In some cases, uncertain legal environments or restrictive foreign investment laws discourage development of mineral deposits. Prospects for the diversification of supply of strategic materials could be improved by coordinating actions by U.S. Government agencies, including the Department of State, the Department of Commerce, the Export-Import Bank, the Overseas Private Investment Corporation, and U.S. participation in international development banks and United Nations activities, to improve both the political and the economic climate for the development of strategic materials in specific countries, A program of this type could be an integral part of U.S. foreign affairs activities, perhaps consisting of a redirection of current resources and efforts rather than a commitment of new or increased Government funds. If desired, however, economic incentives, such as foreign assistance for infrastructure development or special tax treatment for U.S. investors, could be used to promote investment in specified projects,

In all of the approaches to diversify supplies of strategic materials, it is important that the Government target its efforts at specific materials and specific countries. In this way, the effectiveness of the Government's resources can be maximized and side effects, such as the promotion of foreign production of nonstrategic minerals in competition with domestic mines, can be avoided,

Ferroalloy Production Capacity

For chromium and manganese, promotion of diversification of the supply of minerals from the ground is only a partial solution. These metals are generally processed into intermediate products, ferrochromium and ferromanganese, before they are used in the production of steel. A strategy for diversification of supply should consider whether the processing of these ferroalloys is also to be diversified or whether domestic processing of the ores into their alloy form is to be encouraged,

For a variety of reasons, including the use of newer facilities, lower labor costs, reduced transportation costs, and various forms of local government assistance, processing of ores into ferroalloys at or near the mine site has made major inroads into what was once a strong U.S. industry. This is a matter of some concern, that extends beyond the specific interests of the ferroalloy industry, because domestic ferroalloy processing facilities provided a capacity for quick response to interruptions in the supply of imported minerals, If one source of minerals should be cut off, it would be necessary only to expand foreign mine production elsewhere, not to increase capacity of ferroalloy plants as well. With decline of U.S. capacity, it would become more difficult and expensive to maintain production of ferroalloys for steel and stainless steel production in the event that supplies from one of the major producers were interrupted.

In the near term there are no technological fixes to improve the competitive state of the U.S. ferroalloy producers, If domestic capacity is to be maintained, assistance must be of a political or economic nature instead. In the longer term, however, there are several opportunities to increase the competitiveness of the U.S. industry. The U.S. Bureau of Mines could support development of improved technology for existing facilities in order to increase labor productivity and conserve energy and materials. Such improvements, though incremental, could help U.S. facilities compete with more modern facilities overseas, The Government could extend a greater degree of support, largely through policies targeted to encourage investment by U.S. firms to modernize their operations with new processes for the production of ferroalloys. Such processes, which are expected to produce substantial improvements in energy conservation, will be used in new foreign facilities and, to be competitive, U.S. firms must adopt them as well.

Substitution Alternatives

Substitution offers considerable potential to reduce U.S. materials import vulnerability with respect to chromium and, to a lesser degree, cobalt. However, because of the satisfactory performance, reasonable cost, and familiarity of chromium and cobalt containing alloys, there has been little interest in developing, testing, certifying, or using substitutes.

There are three major opportunities for the Government to improve the materials vulnerability status of the United States through substitution:

1. by making information about substitutes widely available to consumers, thus promoting and speeding the adoption of substitute materials;
2. by developing, testing, and, where required, certifying new materials lower in chromium and cobalt content for use in a limited number of industrial applications that account for large fractions of the critical applications for these materials; and
3. by supporting the development of advanced materials, including ceramics, composites, and unconventional metallic compounds, through basic and applied research, education, and the development of design and testing methods appropriate for the new materials,

Substitution Information Systems

During times of chromium or cobalt supply interruptions, interest in substitute materials rapidly increases. However, the period of time required to identify possible substitute materials, test them for particular applications, and modify production techniques for the substitute materials can be quite long. During this period of adjustment, consumers continue to demand these metals, drawing down the available supplies, and resulting in high prices and depletion of producer and consumer inventories. If the shortage is severe, the Government may be forced to allocate supplies to essential applications to the detriment of other industries and consumers. A system that helps users quickly identify and adopt substitutes could reduce the need for strategic materials, particularly in nonessential applications, thereby freeing materials from suppliers and in consumer inventories for use in essential applications.

To be useful, a substitution information system must reflect the needs and concerns of industrial consumers, but, because of its importance to the Nation as a whole as a means of reducing materials supply vulnerability, the Government has a major interest in establishing it. The system would describe current uses of strategic materials, identify the promising alternative materials, and maintain information on the performance of the substitutes and other information users need to determine how to adopt the substitutes.

Although supported by the Government, major elements of the system could be conducted by private sector participants (materials and testing professional societies, trade associations, universities, and individual industries) under Government-established guidelines,

Commercialization of Alternative Alloys

During World War II, the Government established a system of National Emergency Steels for use by industry when shortages of raw materials made it impossible to meet demand for the alloys then in use. Now, laboratory research has identified a number of promising alloys that could become substitutes for the high chromium and cobalt alloys in use today. These alloys are not ready for commercial use because they require further testing in the laboratory, evaluation of production techniques, and evaluation of performance in actual operating conditions, Since these testing and evaluation procedures may take a number of years and several million dollars to complete, the alloys are not "on the shelf, " ready to be used in times of emergency. These alloys do hold promise for reducing the need for chromium and cobalt in critical applications, however. The Bureau of Mines, the National Laboratories of the Department of Energy, NASA, the Defense Department, and the National Bureau of Standards could direct efforts toward testing and evaluation of a limited number of alternative alloys where the potential for strategic material substitution is greatest. To be effective, such an effort would need to have the participation of industry to identify the alternative alloys to be evaluated. This approach is most promising for a number of applications that now use stainless steel. Alternative alloys, low in cobalt, are also possible in superalloy applications, but the high cost of testing and qualification could push costs of a comprehensive program to develop alternatives to the dozens of cobalt-containing superalloy now in use into the hundreds of millions of dollars.

Encourage Development of Advanced Materials

Ceramics, composites, and unconventional metallic materials have properties that suggest they might serve as substitutes for conventional materials that require strategic metals. Basic and applied research is still needed to overcome undesirable characteristics present in the materials and difficulties in the processing of raw materials and the manufacture of components. In addition, design methodologies for use of the materials must be developed to emphasize their advantages and minimize their disadvantages. Finally, up-to-date knowledge of the materials and the associated design and manufacturing technologies must be disseminated to potential users, Three separate activities could further these efforts:

1. *Coordinate Federal* Advanced *Materials R&D:* Research and development on advanced materials is conducted in many parts of the Government, but coordination is achieved largely through personal contacts and professional societies. Programs are developed in response to individual agency objectives, resulting in fragmentation and overlap of research efforts, Although it would be detrimental to attempt to control rigidly all research in advanced materials, increased interagency coordination toward common goals could improve the effectiveness of Government research and speed advances in understanding these new materials. Coordination of Government research is a responsibility of the executive branch, but Congress could further the coordination of Federal research on advanced materials through oversight of the progress of the Administration in preparing its report on the status of Government R&D in advanced materials. Such a report could also raise the visibility of Federal work on advanced materials, resulting in improved coordination with private industry and academic research.
2. *Improve Understanding of Advanced Materials:* Unlike direct substitutes, which may be used in place of current materials with little modification of designs or manufacturing processes, advanced materials will require designs and processes to be developed around their specific properties. This means that academic institutions, professional organizations, and individual firms need to develop programs to train engineers and designers in the proper selection and use of advanced materials. The Federal Government can assist in developing these education programs by providing grants for the hiring of new faculty, acquisition of new laboratory equipment, and design of curricula emphasizing advanced materials.
3. Develop Testing and Certification Procedures *for Advanced Materials:* Reliability and predictability are essential for any engineering material. Until a large body of information on the properties of advanced materials is developed in the laboratory and in the field, industry will not adopt the materials. The same is true for any new material; but in the case of advanced materials the barriers are likely to be greater and the delays longer because testing methods and certification procedures that reflect the special qualities of the materials, and the new design and manufacturing processes that will develop around them, do not yet exist. These barriers could be lessened if Government, industry, and academia focus on developing data on the properties of advanced materials, establish appropriate testing methods, and direct attention to certification procedures to ensure that advanced materials are not restricted from some applications unnecessarily. One approach could be the establishment of a nonprofit center associated with a testing society, professional organization, or academic institution under partial Federal sponsorship for the purpose of overcoming barriers to the use of advanced materials resulting from lack of data as to material properties.

Conservation Approaches

Conservation offers a number of ways to reduce U.S. dependence on foreign sources of supply of chromium, cobalt, manganese, and platinum group metals. In many cases, conservation opportunities are already being implemented, and others are under evaluation by private industry. In the case of manganese, it is likely that improvements in steelmaking technology will continue so that U.S. requirements for imported manganese will decline sharply. Recycling of catalytic converters is just beginning, and several major firms are considering opportunities to expand into this area. Recovery of chromium and cobalt from steelmaking, industrial, and chemical waste has begun to rise in the past few years, driven in part by Federal laws and standards on air and water quality and disposal of waste. Other opportunities are less likely to go forward under normal conditions. Superalloy scrap from obsolete aircraft components, a significant and reliable source of cobalt and chromium, is not likely to be used in the production of new superalloys so long as low-priced metal from foreign sources makes it economically unattractive to invest in the development of new recycling systems.

The promise of conservation of strategic materials—even from those practices already underway—is not assured. The strategic materials recycling industry is new, and our understanding of it is incomplete. Three approaches to improve the prospects for conservation of strategic materials are discussed below.

Update Information on the Recycling of Strategic Materials

Data on the generation and flow of scrap containing strategic materials is incomplete and out of date. The United States is poorly prepared to utilize scrap as a source of strategic materials in times of emergency. With more complete and detailed information, the Government could develop more effective R&D programs to enhance scrap recovery. Congress could direct the Bureau of Mines to conduct, and update on a regular basis, surveys of the generation and disposal of scrap containing chromium, cobalt, manganese, and platinum group metals. Information from these surveys would be useful in planning Government R&D efforts, in updating requirements for the national defense stockpile, and in identifying investment opportunities for private businesses.

Identify Specific Government Actions to Support Recycling of Strategic Materials

In recent years, a number of Federal actions affecting air and water quality and waste disposal have encouraged increased recycling. The potential effects of Government actions on recycling are beginning to receive consideration by policy makers, For example, Government-established freight rates on scrap—previously set at a level higher than the rates for shipping raw material—have been reduced.

The *1980* National Materials and Minerals Policy, Research and Development Act directed the Administration to assess the effects of Federal policies that affect all stages of the materials cycle, including recycling and disposal. A number of recycling activities are new and their economics have not been tested commercially. In some cases these activities may be affected substantially by Government policies. These recycling activities include the recovery of PGMs from catalytic converters, recovery of chromium and cobalt from industrial and chemical wastes, recovery of cobalt from spent hydroprocessing catalysts, and recovery of cobalt and other metals from cemented carbide scrap. Because these recycling industries are small or nonexistent, the effects of Government actions on the recovery of strategic materials from waste or scrap is generally ignored, Yet these sources, combined, could be important supplements to imports of chromium, cobalt, and platinum.

Congress could improve the outlook for conservation of strategic materials by requesting that the Administration identify opportunities to promote the recycling of strategic materials, identify barriers to new or increased recycling, and recommend to Congress ways to structure taxation, procurement, environmental, and other policies to encourage increased recycling. Such a study could be conducted by the Department of Commerce as part of its series of evaluations of strategic materials issues and U.S. industries.

Develop Recycling Technology for Superalloy Scrap

Scrap from processing of superalloys and from obsolete aircraft engine components could provide a secure source of material containing cobalt and chromium metal, At present, only a portion of this supply is reused in superalloy. The remainder is either downgraded to less demanding uses (often completely wasting the cobalt content), exported for use in other countries, or disposed of as waste. Several technical processes to recover individual metals from superalloys have been developed, but so far have only been tested in the laboratory.

The capacity of the United States to respond to cobalt supply disruptions could be enha-need if the Government were to put "on-the-shelf" one or more of the new superalloy recycling technologies by scaling the process up to a demonstration plant. Although relatively costly, on the order of $10 million, such a plant could make available the technology to recover high-quality cobalt from nearly all forms of superalloy scrap. This source was estimated to contain 4 million pounds of cobalt in the year 1980, making it equivalent to several opportunities for domestic mineral production, Estimates of the cost of metals produced from these recycling systems are proprietary, but are said to be in the range of $15 to $25 per pound of cobalt, which is in the same price range as domestic cobalt production.