to increase the conservation and recycling of cobalt, and the substitution of other materials for it, were all begun during this period. Machining techniques for cobalt bearing parts were modified to reduce cutting-floor waste. Recovery of cobalt bearing scrap from jet engine parts, one of the primary sources of cobalt bearing scrap, also increased significantly (see Table 4). In several instances, applied research and experimentation efforts "rediscovered" previously developed cobalt-free (or lower-percentage cobalt) alloys, making substitution possible after demonstration of the necessary metallurgical properties.

Research and development efforts also were directed toward the development of new cobalt-free substitute alloys. Several cobalt-free alloys--expressly developed to equal properties of the cobalt bearing alloys without using cobalt--have just been introduced to the market.[8]

Because of the sensitive nature of aircraft engine design, changes in component parts involve extensive testing. Thus, although waste reduction and improved recycling efforts were instituted fairly quickly, even the introduction of existing "off-the-shelf" alloys into turbine production was not completed until 1981. The substitution of the newly-developed cobalt-free alloys is only just beginning.

Over the 1976-1980 period, cobalt price increases effected an estimated 10 percent reduction in demand for the air and surface engine sector (see Table 6). Again, adjustments to this price increase continue, cobalt-free alloys are appearing in the market, and there is ongoing research and development on additional substitute materials.[9]

Cobalt use in magnet production has a history of sensitivity to price changes. The dramatic price increases of the late 1970s precipitated the introduction of ceramic magnets (barium and iron based and free of cobalt) as substitutes for alnico magnets in a number of applications. A Bureau of Mines industry survey indicates that, as of 1980, virtually all car radios contained ceramic magnets.[10] Thus, over the 1976 to 1980 period, sub-

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8. Teledyne/Vasco advertises VascoMax T-250 as a "new cobalt-free material for high-performance (jet engine) shafts."

9. Although cobalt prices have declined in recent months, the previous price squeeze and supply shortfall still influence perceptions so that substitution away from cobalt continues.

10. Scott Sibley, Mineral Commodities Specialist, Bureau of Mines.

stantial substitution occurred. Cobalt price increases are estimated to have reduced cobalt use in this sector by 22 percent (see Table 6).

TABLE 6. ESTIMATED REDUCTIONS IN AVERAGE YEARLY COBALT END USE DUE TO PRICE INCREASES, 1976-1980 (In thousands of pounds)

Use	Projected a/	Actual	Projected Less Actual	Percent Reduction
Air and Surface Engines	5,087	4,558	529	10
Electrical Components	5,328	4,140	1,188	22
Machinery	4,000	3,032	968	24
Nonmetallic Uses				
Paints	3,135	2,677	458	15
Chemicals	1,886	1,775	111	6
Ceramics	2,419	1,504	915	38
Other Uses	340	340	--b/	--b/
Total	22,195	18,026	4,169	19

SOURCE: CBO calculations.

a. Projections assume that the 1971-1975 average proportion between the relevant industrial production index for that sector and cobalt end use hold true for 1976-1980.

b. Not applicable.

Cobalt use for machine tools witnessed several market adjustments during the 1977-1979 price hike. Cemented carbides averaged about 10 percent cobalt before 1977; by 1981, applied research efforts had enabled its reduction to an average of about 7 percent.11/ Research and development efforts to produce cobalt-free steels for machine cutting tools were initiated in 1977, and continue today. Cobalt-free maraging (high-strength) steels have recently entered the market, and industry sources suggest that

11. Conversation with Scott Sibley, Bureau of Mines.

cobalt-free tool steels are not far behind.12/ Over the 1976 to 1980 period, cobalt price increases generated an estimated 24 percent reduction in cobalt consumption for this end use (see Table 6).

Cobalt's use in nonmetallic applications appears to have been affected appreciably by the 1977-1979 price rise. Estimates indicate that use of cobalt in both paint and ceramics was reduced 15 and 38 percent, respectively (see Table 6). Some of the reduction in cobalt usage in paint production may be the result of the trend toward water-based (or cobalt-free) paints. Moreover, ongoing industrial research efforts, aimed at recapture of cobalt used in catalysts, may provide a significant, and heretofore untapped, secondary source of cobalt.

Conclusion

The demand for cobalt has shown an upward trend in the last 20 years. But sharp price increases in the late 1970s led to considerable substitution for cobalt in a number of end uses.

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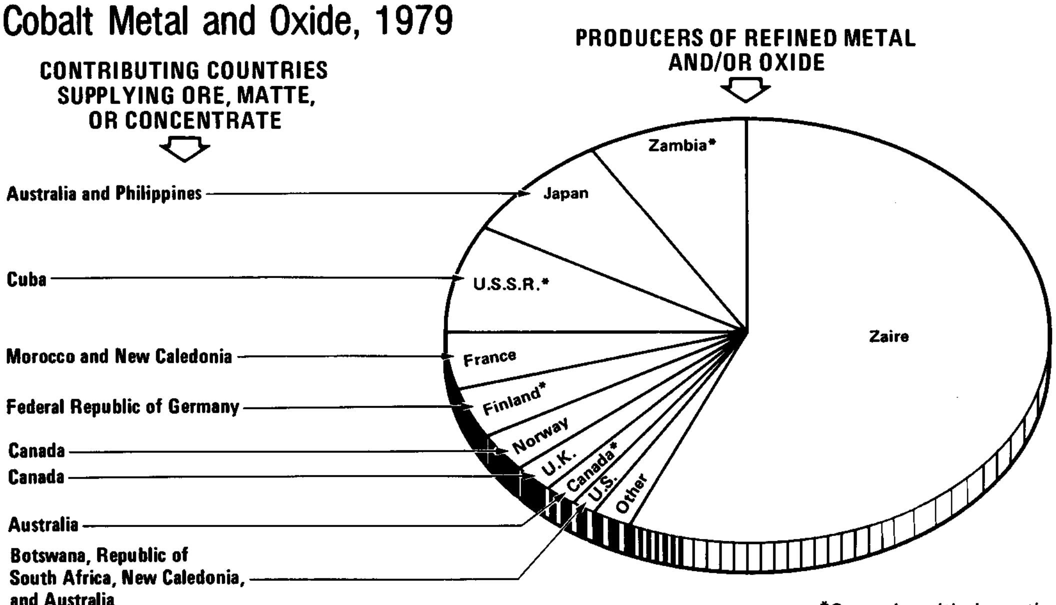
12. Conversation with Teledyne/Vasco.

World Resources

Central Africa clearly dominates the world's cobalt supply picture (see Figure 3). Zaire leads by far, both in the mining of cobalt-bearing ore and in cobalt production, accounting for 53 percent of the world's supply of refined cobalt in 1979--virtually all of it from its own mine production. Estimates of the world's proven reserves of cobalt show much the same picture (Table 7). Moreover, geologists stress that the cobalt-bearing formations in Zaire and Zambia are significantly richer than other known deposits.

Since cobalt is typically produced as a by-product, usually with copper or nickel, cobalt output has not been sensitive to cobalt price increases.

Figure 3.
Distribution of Estimated World Production of Refined Cobalt Metal and Oxide, 1979



SOURCE: U.S. Bureau of Mines, *Mineral Facts and Problems* (1980), p. 201.

*Countries with domestic production.

TABLE 7. WORLD COBALT RESERVES FOR 1979 (In million pounds)

	Reserves
North America	
United States	0
Canada	60
Cuba	400
Total	460
Europe	
Finland	40
U.S.S.R.	500
Total	540
Africa	
Botswana	60
Morocco	100
South Africa	50
Zaire	2,600
Zambia	800
Total	3,610
Oceania	
Australia	100
New Caledonia	200
Philippines	400
Total	700
World Total (land-based) a/	5,300

SOURCE: Mineral Facts and Problems, p. 204. Reserves are defined as cobalt deposits that can be worked at current market prices.

a. Data may not add to totals shown because of independent rounding.

The prices of nickel and copper have historically determined the rate at which multi-mineraled cobalt-bearing ores have been mined. Recent price increases, some contend, have elevated cobalt to co-product status, rendering cobalt of consequence in decisions about production rates. In fact, suppliers in recent years have, in response to price increases, invested in improvements in cobalt capture and in expansion of processing capability.

U.S. Domestic Supplies

The United States has not produced cobalt (excluding scrap recovery or refinement of imported ores) since the cessation of subsidized cobalt production during the Korean War. Two U.S. cobalt deposits--the Blackbird deposit in Idaho and the Madison mine in Missouri--drew private investment in 1980. But recent price declines, the likelihood that Zaire would seek to undercut any U.S. competition, and the general downturn in the economy have halted development efforts at these two sites.

The salient statistics for these two mines (see Table 8), reveal both their promise and their problem. Potential production levels are appreciable, perhaps 6 million pounds per year (38 percent of 1980 U.S. consumption). But the price per pound required to justify the necessary investment is estimated by the mining companies in the $20-$26 range. Any strategic advantage to be derived from having these mines in operation must, therefore, be weighed against the cost of subsidizing them, unless prices rise again.1/

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1. The issue of domestic reserves as a standby is discussed in Chapter V.

TABLE 8. PRINCIPAL U.S. COBALT DEPOSITS

	Reserves (millions of pounds of cobalt)		Estimated Production Rates from Proven Reserves (millions of pounds of cobalt per year)	Estimated Duration of Production (years)	Necessary Start-Up Time Time Before Production Begins (years)	Estimated Price of Cobalt Necessary for Mines To Be Economic (dollars per pound)
	Proven	Potential				
Blackbird	70	100-150	3	12	3-4	24-26
Madison	20		2	10	3-4	20
Missouri Additional	10-15		1-1.5	10	3-4	20

SOURCE: Statements by representatives from Anshutz and Noranda Mining Companies, hearings before the Committee on Banking, Housing, and Urban Affairs, United States Senate, 97th Congress, October 26, 1981.

CHAPTER IV. THE COBALT MARKET IN THE 1980S AND THE COSTS OF DISRUPTION

This chapter provides a baseline assessment of U.S. cobalt demand and potential supply problems in the 1980s. It also provides estimates of the costs of supply disruptions, given the baseline forecasts for cobalt demand and the potential for market adjustment.

The projections of demand and supply for the cobalt market suggest that the United States will continue to rely exclusively on imports for its supplies. This justifies some contingency plan to provide cobalt for defense purposes during wartime. Additionally, political upheavals in Central Africa could have a profound impact on the cobalt market. For a wide range of such nonmilitary shortfall scenarios, however, the costs to the United States appear to be quite limited in size and scope.

Demand Projections

U.S. and world cobalt demand is adjusting to the new cobalt price regime. The long lead times necessary for price-related adjustments in a number of cobalt end uses suggests that substitution away from cobalt, as a consequence of the 1977-1979 price hikes, continues today. Nonetheless, U.S. cobalt demand should grow moderately throughout the 1980s. The Department of Interior's Office of Minerals Policy and Research Analysis (OMPRA) and the Department of Commerce have recently constructed world market models for cobalt. Their projections of approximately 25 million pounds of cobalt consumption for 1985 and 29 million pounds for 1990 reflect reduced growth in cobalt demand resulting from higher prices. Again, the time lag before many adjustments in cobalt use become apparent may soon render even these projections too high. Examination of the future for traditional cobalt end uses reveals a host of possibilities for reduction in domestic demand.

Expanded production of a wide variety of air and surface gas turbine engines should generate steady cobalt demands for this end use. Defense expenditures are slated for significant increases, the commercial airlines fleet is aging and in need of replacement, and projections for gas turbines for electrical power and pumping engines are substantial. At the same time, the use of cobalt in the production of many of these engines may decline significantly. Research and development efforts aimed at developing cobalt-free alloys have already reduced some of the need for cobalt.

Moreover, industry representatives point to advances in techniques such as "rapid solidification" of alloys, and suggest that cobalt use in this sector may be reduced by as much as 50 to 80 percent by the year 2000.1/

Future levels of cobalt use for electrical equipment are highly uncertain. Projections for expanded markets in electronic devices suggest additional uses for cobalt bearing magnets. Ceramic magnets, however, have replaced many cobalt bearing magnets and may be introduced in a number of other applications. The technology exists today to replace the cobalt used in the annual U.S. production of ten million phones.2/ Ceramic magnets have made significant inroads in a number of motor vehicle applications.3/ Clearly, demand in this end use is changing rapidly. Thus, there is potential in this sector for fairly rapid substitution for many uses of cobalt.

Future cobalt demand for machinery appears to be fairly strong. Cemented carbides production continues to require cobalt, although in reduced proportions. As previously noted, however, substitutes are appearing for a number of cobalt bearing alloys for use in tool steels. Finally, as previously discussed, future demand for cobalt for nonmetallic uses, although potentially large, is now subject to the results of considerable research in both conservation and substitution.

Thus each of the categories that make up the total need for cobalt in the United States is, in varying degree, in a state of transition. Barring a supply disruption, total apparent consumption of between 25 and 30 million pounds of cobalt per year in the years 1985 to 1990 appears to be a reasonable estimate. Potential for substitution away from cobalt is significant, however, so that demand could turn out to be appreciably less than these projections.

Potential Supply Problems

Long-term depletion is not a problem for cobalt, since Zaire and Zambia appear to have ample supplies to meet the demand of the Western economies for decades to come. Moreover, ocean mineral resources may also produce significant quantities of cobalt in the future.

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1. Department of Commerce, Critical Material Requirements of the U.S. Aerospace Industry (October 1981), p. 287.

2. Ibid.

3. Conversation with Scott Sibley, Bureau of Mines.

Strategic concern over cobalt arises from the short- and mid-term threat of sharp price increases and supply disruptions. Zaire's dominance of the market means that sudden price ratchets cannot be ruled out. Moreover, political instability in Zaire and Zambia makes extended supply disruptions a possibility. The likelihood that political instability will at some time lead to supply shortfalls cannot be assessed with much certainty, although political analysts are in general agreement that in Zaire and Zambia it is significant. Under the auspices of the Office of Minerals Policy and Research Analysis of the Department of the Interior, a panel of political and mineral experts constructed a range of possible political futures for these nations. For each future, the panel then assessed the probability, magnitude, and duration of cobalt supply shortfalls. The experts concluded that in the 1980s there is a greater than 0.3 probability that a significant shortfall could occur in Zairian output. For the "worst case" political scenario, the probability exceeds 0.7. A similar conclusion was reached for Zambia.[4] There was, however, general agreement that any disruption occurring in central African supply would be limited in size. An extended disruption curtailing all of supplies from Zaire and Zambia was given almost no chance of occurring.

Costs of Disruptions

The costs to the United States of a given supply shortfall would depend on the demand for cobalt, on the general level of economic activity, on the existence of alternative supply sources, on the levels of cobalt inventories, on the possibilities of substituting other materials, and on the policy actions undertaken.

Private inventories (averaging between four and six months of U.S. demand in 1975-1979) would provide an initial buffer. The pipeline of conventional refined cobalt through Belgium should also provide several months of supplies to the world cobalt market following a central African

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4. The threat in Zaire is guerrilla insurrection. In Zambia, a military confrontation with either Zimbabwe or South Africa could upset production.

disruption.[5] Cobalt scrap recovery has, over the past decade, increased along with cobalt prices; at least 7 percent recycling can be expected, and perhaps 10 to 20 percent is achievable.

A major supply shortfall would no doubt be accompanied by extreme price increases, as high as $100 per pound, thus motivating appreciable substitution. In the electrical end use, substitution could be extensive. In uses that are acutely dependent on the metal (such as engines), manufacturers would be forced to pay greatly inflated prices. Nonetheless, they could be expected to bid successfully for the cobalt available in the market as they did in 1977-1979. Some expansion in production and/or improvement in capture of cobalt from suppliers unaffected by the disruption could also be expected. Although cobalt supply is relatively insensitive to price, because cobalt is predominantly a by-product, the significant price increases generated by a disruption should induce some additional output. Finally, it is the nature of extreme situations that they provide incentives to find alternative approaches that, until the crisis was at hand, had not been considered.

Quantitative estimates of the costs of a number of hypothesized supply shortfalls have been made by the Department of Interior's Office of Minerals Policy and Research Analysis and by the Commerce Department. Even in the most extreme case, market adjustments would limit the costs to the U.S. economy. The costs would consist largely of the payment of higher prices for cobalt and cobalt substitutes, with no appreciable shutdown of economic activity.

The cobalt market model of the Office of Minerals Policy and Research Analysis (OMPRA) was used to estimate the economic effects of supply shortfalls. Assessments of the likelihood of various political outcomes for Zaire and Zambia were combined with estimates of each outcome's effect on cobalt output. These yielded a probability-weighted average cost to the United States of $540 million.[6] The "best case"

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5. The OMPRA study assumes that a three-and-one-half-month world supply of cobalt is available. It notes that typically seven-month stocks exist outside central Africa, but that some will not become available due to speculation. See U.S. Department of the Interior, Office of Minerals Policy and Research Analysis, Cobalt: Effectiveness of Alternative U.S. Policies to Reduce the Costs of a Supply Disruption (August 1981), p. III-10.

6. This figure represents the average of the discounted expected values of the costs of the various possible outcomes in 1980 dollars. U.S. Department of the Interior, Office of Minerals Policy and Research Analysis, Cobalt, p. III-15.

scenario involves no supply shortfalls and therefore its cost is zero; for the "worst case" political assessment, the cost remains moderate, an estimated $1.44 billion discounted. OMPRA also examined an extremely severe (and considered highly improbable) two-year shortfall for both Zaire and Zambia in 1985-1986. In this case U.S. consumption does drop significantly, by an estimated 20 percent in 1985 and 35 percent in 1986. But the reduced cobalt consumption is made possible mostly by substitution, with little lost economic output envisioned. The costs in 1985 and 1986 are estimated to be around $1.0 billion and $1.8 billion, respectively. The total discounted cost over the years 1985-1990 for this extreme shortfall is an estimated $1.8 billion.7/

The Commerce Department employed a cobalt market economic model to assess the impact of one hypothesized shortfall, a 75 percent reduction in output for both Zaire and Zambia in 1985.8/ Its results are similar to those of the OMPRA. Costs in terms of cobalt purchases are much higher, however, jumping from $350 million in 1985 without a disruption to about $3 billion.9/ U.S. consumption falls by 23 percent in 1985, mostly through forced substitution. As with the OMPRA analyses, however, little lost output is envisioned.

Effects of Price Increases

Major cobalt price increases, the second potential cobalt market problem, have occurred in the recent past. They led to higher costs for cobalt users, as well as increased costs for substitutes. Such increases can be devastating to particular cobalt users.

For the economy as a whole, however, major cobalt price increases are of little significance. If the price of cobalt were to increase to $112 per pound in 1985 (an extreme price increase), and if cobalt imports were to total 25 million pounds in 1985 (perhaps an overestimate, given substitution possibilities), the undiscounted additional payments to cobalt suppliers in that year would be $2.5 billion. This is less than 1 percent of the value of U.S. merchandise imports in 1981 and 5 percent of the 1981 U.S. imports

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7. This figure represents the discounted social cost of the two-year shortfall, in 1980 dollars (see Cobalt, p. III-4).

8. Department of Commerce, Critical Material Requirements. The study does not attempt to justify the hypothesis.

9. These figures are 1979 dollars.

from countries belonging to the Organization of Petroleum Exporting Countries. The inflationary pressures associated with the additional expenditures would be less than 0.1 percent.10/

Conclusion

Only a wartime scenario, with shipping and airlanes blocked and a complete cutoff of cobalt imports, would justify a contingency plan for defense needs. Otherwise, even for extreme and highly improbable cutoffs of African cobalt supply, significant plant closings or substantial losses in economic output would not be expected. The aerospace industry would not be forced into major work stoppages. Large price increases could be costly to particular firms, but would not have a significant effect on the economy. It is against this backdrop that policy options for cobalt are examined in the following chapter.

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10. Assuming the price increase was completely passed forward to the prices of final products, and ripple effects occurred throughout the economy.

CHAPTER V. POLICY OPTIONS

A wide range of policy options have been suggested as means to reduce America's vulnerability to cobalt supply shortfalls. This range includes:

- o Improved management of the strategic stockpile;
- o Creation of an "economic stockpile" for nonstrategic uses;
- o Subsidized domestic cobalt production;
- o Increased funding for research and development efforts to expand the supply of cobalt and its substitutes;
- o Expanded access to public lands for mineral exploration and development; and
- o Accelerated development of ocean mineral resources.

Each of these options is considered below.

Strategic Stockpile

The Strategic and Critical Materials Stockpiling Act, as amended in 1979, requires the stockpiling of cobalt to supply military, industrial, and essential civilian needs of the United States for national defense.1/ The act stipulates that stockpile levels be sufficient to enable the continued functioning of the U.S. military and industrial sectors, unencumbered by supply considerations, during the conduct of a three-year war. The stockpile goal for cobalt, as of November 30, 1981, is 85.4 million pounds; 42.0 million pounds, or 49 percent of the goal, had been stockpiled by the spring of 1982.2/ At the producer price of $12.50 per pound in May 1982, an expenditure of $542.5 million would be necessary to fill the stockpile.

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1. The Strategic and Critical Materials Stockpiling Act of 1946 required stockpiling to "supply industrial, military, and naval needs of the country for common defense." The 1979 revision adds the "essential civilian" category.

2. Bureau of Mines, Mineral Commodity Summaries, 1982, p. 36.

As noted previously, an extreme supply shortfall resulting from political/military action in Africa could result in a very tight world cobalt market. But cobalt would still be available from other suppliers, at high prices. The strategic stockpile is designed to meet a much more extreme wartime situation in which the nation would be mobilizing its industrial war machine without access to imports.

At the present price for cobalt of $12.50 per pound, stockpiling may be the least expensive means to provide for defense needs in time of war.3/ Estimated costs of domestic production are $25.00 per pound (see the following section).

The appropriate level for cobalt stockpiling has been a contentious issue for decades, as seen in Chapter I. The analysis that results in stockpile goals is performed by the Federal Emergency Management Agency (FEMA). FEMA employs historical relationships between industrial sectors' output levels and their cobalt consumption rates, postulates industrial output levels assuming a war economy, and combines these figures to estimate cobalt requirements.

Given FEMA estimates of wartime needs for cobalt, the present stockpile is only 49 percent full. At the present level, however, the cobalt stockpile affords the United States about two-and-one-half years' supply if consumed at 1979 rates. More importantly, estimates of direct military uses for cobalt in 1979 indicate that only 17 percent of the total cobalt consumed that year was used for military purposes.4/ Thus the present stockpile would be sufficient for many years of defense uses, given 1979 consumption levels.

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3. A related option would be to increase business inventories of cobalt. Under current Department of Defense regulations, a contractor is not allowed to itemize inventory interest costs as an allowable charge to a DoD contract. Recently, it has been suggested that this practice be changed. Lower carrying costs would induce users to increase their inventories, thus raising the amount of cobalt of appropriate quality available to those users considered most essential. On the other hand, if the government paid all interest costs on inventories of defense users, it would be financing the carrying costs of a great deal of cobalt that they already held. Thus the benefit of enlarged private inventories must be weighed against the cost of subsidizing existing inventories that were heretofore financed by the private sector.

4. Congressional Research Service, U.S. Economic Dependence on Six Imported Strategic Non-Fuel Minerals (July 1982), p. 38.

A range of stockpile goals is provided in Table 9 for illustrative purposes. Each stockpile goal is calculated to accommodate three years of consumption according to a particular estimate of U.S. cobalt needs. For 1980 consumption levels (the peak levels recorded) and for 1985 consumption projections, each of the following criteria are considered: the needs of all cobalt consumers; the needs of direct military consumers; the requirement of a doubling of consumption by direct military consumers; and the needs of all military and civilian aerospace industry consumers.

As Table 9 shows, the present stockpile goal of 85.4 million pounds is more than enough for three years of consumption by all cobalt users at projected 1985 levels. It is significantly above the level necessary to accommodate three years of consumption (at projected 1985 levels) for the aerospace industry or for direct defense needs.

The cost of each option is shown in the third row of the table, assuming the June 1982 price for cobalt of $12.50 a pound. For a number of the options examined, the cobalt on hand in the strategic stockpile exceeds the amount calculated to be necessary, thus providing a potential source of savings. The present goal for the cobalt stockpile is larger than the goal calculated to be necessary for all but one of the cases presented. The bottom row of the table provides estimates of the savings that would be made if the present goal was reduced to meet the requirements of each option.

Clearly, a wartime economy would require significantly greater defense-related expenditures in a number of industries that use cobalt. The slated defense buildup for the 1980s will probably increase the present peacetime need for cobalt. Under present law the stockpile must provide for not only defense but industrial and essential civilian needs. Nevertheless, the strides made in developing cobalt substitutes (and the continuing effort in this area) suggest that it may be appropriate to reassess the stockpile requirement. Reducing the goal would, of course, reduce the cost of this option.

The present stockpile goal would provide for at least three years of consumption at wartime levels. This would allow sufficient time to bring significant domestic mine production on line. As noted earlier, domestic mining concerns estimate that within three to four years an annual capacity of six million pounds of cobalt could be brought on line. This timeframe may be optimistic since the production schedule estimates are based on recently completed preliminary mine site preparations, which might have to be redone in the future. Nonetheless, a wartime economy could make domestic cobalt production a priority and accelerate activities. During World War II, the United States increased its cobalt production from zero in

TABLE 9. EXAMPLES OF ALTERNATIVE COBALT STOCKPILE GOALS

	1980 Base			
	Cobalt Consumption (Total) a/	Direct Military Cobalt Consumption b/	Doubling Direct Military Cobalt Consumption	Total Aerospace Industry Requirements c/
One-Year Supply (millions of pounds)	17	2.9	5.8	6.2
Three-Year Supply (millions of pounds)	51	8.7	17.4	18.6
Cost of Purchases Necessary for a Three-Year Supply (millions of dollars) e/	112.5	(416.3)	(307.5)	(292.5)
Potential Budgetary Savings (millions of dollars) f/	430	958.8	850	835

NOTE: Figures in parentheses are revenues obtained through sale of excess cobalt.

a. U.S. Bureau of Mines, Mineral Commodity Summaries, 1982.

b. Congressional Research Service, U.S. Economic Dependence on Six Imported Strategic Non-Fuel Minerals (July 1982). An estimated 17 percent of cobalt consumption was in the production of defense goods in 1979. This percentage was used to estimate 1980 and 1985 cobalt defense needs, as a proportion of projected total consumption for cobalt. Given the significant increases in outlays for defense projected for the 1980s, a doubling of cobalt used for defense is also provided.

c. U.S. Department of Commerce, Critical Materials Requirements of the U.S. Aerospace Industry, p. 56. The report presents three scenarios of cobalt demand: a base case without substitutions and conser-

TABLE 9. (Continued)

1985 Projection				
Cobalt Consumption (Total) d/	Direct Military Cobalt Consumption b/	Doubling Direct Military Cobalt Consumption	Total Aerospace Industry Requirements c/	Total Cobalt Consumption with Military Cobalt Consumption Doubled
25	4.2	8.4	8.4	29.2
75	12.6	25.2	25.2	87.6
412.5	(367.5)	(210)	(210)	570
130	910	752.5	752.5	(27.5) g/

vation; a case with substitution and conservation efforts reducing cobalt needs; and a third upper-bound case, which is an attempt to capture the "maximum requirements for cobalt over the projected years." The figures used in this table are the upper bound.

d. U.S. Department of Commerce, ibid.

e. This estimate assumes that cobalt is either purchased or sold at its May 1982 price, $12.50 a pound. It also includes the 42 million pounds of cobalt presently stockpiled.

f. This estimate reflects the difference in cost of meeting the goal in question rather than the present cobalt stockpile goal of 85.4 million pounds.

g. This figure represents the total expenditures necessary in addition to those required to reach the present goal.

1939 to over 500,000 pounds in 1941 and 1.28 million pounds in 1946--the latter representing 12 percent of world production.5/

Whether the cobalt currently in the strategic stockpile is of acceptable quality is also the subject of debate. The National Materials Advisory Board of the National Academy of Sciences has noted that existing stores of cobalt, for the most part, were purchased over 20 years ago, and may be unfit for many of today's specialized uses.6/, 7/ An assessment of the quality of existing stocks, together with a strategy for continual quality control, may be advisable.

The stockpile could be used to reduce the impact of peacetime shortages. Given an extreme shortfall in world cobalt supply, the President could opt to release cobalt from the stockpile for defense-related uses. This would dampen price increases, reducing costs to cobalt consumers and lessening the need for substitution of other materials--thereby reducing the social cost to the United States of such a shortfall.8/ But depleting the stockpile for this purpose would reduce its effectiveness in its statutory function, the supplying of cobalt for a three-year war.9/

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5. Charles River Associates, Policy Implications of Producer Country Supply Restrictions: The World Cobalt Market, CRA Report #220 (August 1976), p. 43.

6. National Materials Advisory Board, Commission on Sociotechnical Systems, National Research Council, NMAB-378, Considerations in Choice of Form for Materials for the National Stockpile (1982).

7. Cobalt's applications in alloys for aerospace require extremely pure cobalt ingots; cobalt purchased in the 1960s was tested for purity using methods that today are considered inadequate.

8. The Office of Minerals Policy and Research Analysis estimated the social cost to the United States of a two-year supply cut-off from Zaire and Zambia, with and without stockpile releases from the U.S. stockpile, and found that the social cost was reduced from $1.840 billion to $1.144 billion (see Cobalt, p. III-15).

9. Moreover, a nonmilitary market squeeze would heighten concern about future cobalt supplies for military production and probably make stockpile releases politically difficult.

Stockpile for Nonstrategic Uses

A separate "economic stockpile," designed to mitigate shortfalls for nonmilitary uses, would reduce the costs of such an event to cobalt consumers. This would probably be an expensive insurance policy, however, in terms of the risk to be insured. The OMPRA cobalt market model evaluated the discounted costs of its panel average of disruption scenarios with a consumer stockpile in place and found the discounted costs of this policy exceed the present policy cost of $540 million by $80 million.10/

An economic stockpile would, during its accumulation, increase the U.S. demand for cobalt, putting upward pressure on its price. Stockpiling, whether for the strategic stockpile or an economic stockpile, also involves carrying costs, storage logistics problems, and quality problems. An economic stockpile would presumably serve all U.S. cobalt users, and therefore expand dramatically the magnitude of each of these concerns. It could also reduce the incentive for private companies to keep (and pay for) sufficient private inventories.11/ Finally, it could reduce incentives for private-sector exploration for substitutes.

Subsidization of Domestic Mine Production

When prices were high in 1980, proposals were made to subsidize the domestic production of cobalt. It was estimated that up to a dozen years of domestic cobalt production of six million pounds per year (37.5 percent of 1980 primary cobalt demand) would be achievable. Domestic mine production could alleviate world cobalt market tightness in the event of a supply shortfall, thereby reducing the need for adjustment by cobalt users. Domestic mine production could also deter major price increases to the degree that it responded to them with increased output.

Benefits from domestic production would have to be weighed against costs incurred. According to the mining companies with the best prospects, a floor price would have to be set in the $25 range and guaranteed for at least ten years. Twenty-five dollars per pound is significantly above today's cobalt price ($12.50 per pound), and only marginally below the peak price of 1980. It is also considerably above most price projections for the 1980s. Table 10 shows what the annual costs of such a subsidy would be at different market prices. Although these costs are not large, ranging up to

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10. Cobalt, p. III-15.

11. Department of Commerce, Critical Materials Requirements, p. 230.

TABLE 10. ANNUAL COSTS OF COBALT MINE SUBSIDIZATION

Floor Price for Cobalt (dollars per pound)	Market Price for Cobalt (dollars per pound)	Annual Cost of Subsidy (millions of current dollars) a/
25	3	132
25	5	120
25	7	108
25	10	90
25	12	78
25	15	60
25	20	30
25	25	0

a. Assuming production of six million pounds per year.

$132 million a year (assuming production of six million pounds per year), they must be seen as a form of insurance against a hazard that is not likely to occur. If cobalt prices remained at $12.50, and if cobalt domestic production was subsidized for ten years at $25 per pound, the present value cost of this subsidy (assuming a 2 percent discount rate) would be $673 million. This would do no more than to put domestic production in place; it would not guarantee supplies for U.S. consumers, nor would it provide for defense needs after the ten-year period. Since only the most extreme case of cobalt supply disruption would incur significant costs, the highly unlikely probability of the extreme case makes domestic mine subsidization appear, like economic stockpiling, to be an expensive insurance policy.

Moreover, the subsidizing of domestic cobalt production could be expected to reduce the search for substitutes that was spurred by the recent upsurge in prices.

Finally, domestic reserves of cobalt are limited (see Table 8). In effect, they represent a stockpile with a time lag. Subsidizing their exploitation would eliminate the time lag, but eventually eliminate the stockpile as well.

Support for Research and Development

Research and development efforts promise innovations that could reduce significantly U.S. vulnerability to cobalt shortfalls, both by expanding supply and improving the performance of cobalt substitutes. Basic research appears to be most in need of support. Coordination of government research, and joint development efforts by government, industry, and academia have also been recommended.

The federal government accounted for approximately one-half of U.S. expenditures on research and development in fiscal year 1980. It devoted 4 percent of its total research and development budget to materials R&D, funding 20 percent of the country's $5.4 billion expenditure on R&D in the area of materials. Private-sector investigators actually perform much of the R&D in materials research for the federal government. In fiscal year 1980, 26 percent of the federal expenditures were in-house; 30 percent were in non-civil service laboratories; and 42 percent were in the private sector (23 percent in industry, 19 percent in universities).12/

Concern about the level and scope of R&D in the United States has prompted numerous academic organizations (including the National Academy of Sciences and the National Commission on Materials Policy) to call for government funds to help extend the base of scientific knowledge for new materials applications. The benefits from basic research efforts generally extend beyond those directly involved. This makes it difficult for private firms to underwrite extensive basic research and development efforts, since they may be costlessly benefiting their competitors. Yet basic research promises fundamental breakthroughs that can result in extraordinary improvements in the nation's material position. The development of fiber optics communications, for example, a product of basic research efforts with lasers may substantially reduce the need for copper.

The cobalt price hike of the late 1970s generated considerable private-sector R&D directed toward development of cobalt-free alloys. Such efforts have produced a number of cobalt-free substitutes. Industry R&D can be expected to expand given the new tax credit for such expenditures (25 percent above a three-year average). A recent business survey indicates that, overall, business plans to spend $59.7 billion on R&D during 1982, an increase of 17 percent from 1981 levels.13/ Industry sources, particularly in the aerospace industry, indicate that R&D materials substitutes will receive significant attention.

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12. Ibid., p. 267.

13. Washington Post, May 28, 1982, p. D.10, citing a McGraw-Hill Publications Company survey.

An expansion of R&D in the field of mineral supplies has also been recommended. The Geophysics Study Committee of the National Research Council proposed increased research, undertaken jointly by government, industry, and academia, to improve understanding of the basic process of mineralization.[14]

Access to Public Lands

Access to public lands for the exploration, development, and mining of cobalt has also been proposed. Mining spokesmen contend that "benign exploration" of public lands, particularly in Alaska, might discover cobalt-bearing ores of higher grade, comparable to central African ores. Were "benign exploration" permitted to advance to development and mining, assuming discovery of economically recoverable cobalt ores, strategic vulnerability to a cobalt shortfall would be reduced. The nature of "benign" exploration, however, is a contentious issue.

Debate exists as well over the nature and extent to which lands are removed from access to mining concerns. Although this study did not address these issues explicitly, it should be emphasized that justifying, on national security grounds, the exploration, development, and mining of cobalt on public lands translates to a decision to allow such development to help reduce the economic losses that accompany a supply shortfall. As previously discussed, such a shortfall involves major price increases and much adjustment, but plant closings or significant lost economic output are not envisioned.

Development of Ocean Mineral Resources

Deep-sea nodules contain vast amounts of cobalt (along with manganese and nickel).[15] Estimates indicate that the amount of cobalt in these

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14. Mineral Resources: Genetic Understanding for Practical Applications (National Academy Press, 1981).

15. Polymetallic sulfides, another ocean mineral resource recently identified, contain significant quantities of copper, zinc, lead, silver, and other metals, and possibly cobalt. Scant information exists on the nature and extent of these deposits. See "Ocean Minerals/Polymetallic Sulfides: Should the United States Legislate for Future Development?" Congressional Research Service, Minibrief, 4/12/82.

ocean floor nuggets may be over 500 billion pounds.16/ Several impediments remain to nodule production and little output from this source can be expected in the next decade. But in the long run, there is potential for capture of large quantities of cobalt and other metals.

If development of deep-sea nodules proves cost-effective, it promises several benefits. Successful exploitation of manganese nodules by U.S. firms should provide U.S. cobalt consumers with a steady long-term supply of cobalt at relatively stable prices. The U.S. strategic position vis-a-vis cobalt would be improved, and U.S. payments for metal imports reduced.

U.S. firms are involved in four multinational consortia, which, along with a French industry/government consortium and a Japanese consortium, comprise the present manganese nodule development effort. None of these consortia has passed the research and development stage, nor has any of the private consortia committed itself to commercial-scale operations. Technological, economic, and institutional barriers continue to bar the way to commercial development. Estimates indicate that $150-250 million of additional research and development per consortium are necessary, and that a commercial-scale system will require a capital investment of well over $1 billion.17/ Moreover, potential developers are unwilling to proceed without a clearer picture of the political climate for development--that is, they need to understand better the "international rules of the game" that will regulate ocean mining enterprises.

Taken together, these prerequisites to nodule development put private production at least a decade away. The limited nature of U.S. vulnerability to cobalt shortages suggests that direct subsidies to accelerate commercial production would, as already noted, be an expensive insurance policy. However, diplomatic efforts to establish the "rules of the game," and federal efforts to minimize other institutional barriers to development, might speed private development of nodules without a large expenditure of public dollars.

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16. Bureau of Mines, Mineral Facts and Problems (1980 edition), p. 204.

17. Department of Commerce, Critical Materials Requirements, p. 275.

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