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Industry Study

Final Report
Strategic Materials Industry

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ABSTRACT: Ensuring availability of materials has been important throughout civilization, dating back 4000 years when the Egyptians stockpiled supplies. Our nation's leaders are tasked with assuring the adequacy of supplies of materials required for national security by developing policies that shape the way strategic materials are defined, produced, and traded. These policies, constructed in the often messy legislative process against a backdrop of competing interests and factions, are a collection of disparate laws, regulations and procedures. The current set of materials policies does not provide assurance of supply of strategic materials. Fortunately, there are no significant shortfalls of materials needed to meet near-term strategic requirements. However, continued reliance upon an uncoordinated patchwork of legacy policies would be imprudent, particularly since the nation has recently experienced issues with respect to the availability of beryllium, titanium, and rare earth metals. Therefore, the US government needs to establish a legal framework in which the DoD and other executive branch departments and agencies are enabled to implement risk-informed policy actions in a timely and agile manner.

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ACRONYMS AND ABBREVIATIONS

BAA - Buy American Act
CBO - Congressional Budget Office
CFIUS - Committee on Foreign Investment in the United States
DLA - Defense Logistics Agency
DoC - Department of Commerce
DoD (or DOD) - Department of Defense
DOE - Department of Energy
DPA - Defense Production Act
DPAS - Defense Priorities and Allocations System
ELI - Environmental Law Institute
FTA - Free Trade Agreements
HPB-High purity beryllium
ITAR - International Traffic in Arms Regulations
MOU - Memorandum of Understanding
NAFTA - North American Free Trade Agreement
NEPA - National Environmental Policy Act
NMA - National Mining Association
NSTC - National Science and Technology Council
REE - Rare earth elements
SMCRA - Surface Mining Control and Reclamation Act
SMP – Specialty Metal Provision
SMSP - Strategic Materials Security Program
SQM - Sociedad Química y Minera de Chile S.A.
STEM - Science Technology Engineering Mathematics
U.S.G.S. - United States Geological Survey
US (or U.S.)- United States
USTR - United States Trade Representative
WTO - World Trade Organization
XSORBX® - a water purification product from the Molycorp Company

PLACES VISITED

Domestic Locations:

National Capital Region:
United States Geological Survey, Reston, VA
Army Research Laboratory, Aberdeen, MD
Senate Committee on Energy and Natural Resources, Hart Senate Office Building

Colorado:
Henderson Molybdenum Mine, Empire, CO
Colorado School of Mines, Golden, CO
Molycorp Minerals, LLC, Greenwood Village, CO

Ohio:
Advanced Materials Group (ADMA), Hudson, OH
The Timken Company, Canton, OH
RTI International Metals, Inc., Niles, OH
General Electric Aviation, Cincinnati, OH
Materion (formerly Brush Wellman), Elmore, OH

Pennsylvania:
Electron Energy Corporation, Landisville, PA
Carpenter Technologies, Reading, PA
Titanium Metals Corporation, Morgantown, PA

Virginia:
Iluka Resources Titanium Mine, Stony Creek, VA

International locations:

Chile:

National Mining Association - SONAMI (Sociedad Nacional de Minería). Santiago
Ministry of the Environment (Ministra de Medio Ambiente), Santiago
National Geological and Mining Service - SERNAGEOMIN (Servicio Nacional de Geología y Minería), Santiago
National Copper Corporation of Chile - CODELCO (Corporacion Nacional del Cobre), Santiago
Chilean National Copper Council - COCHILCO (Comision Chilena del Cobre), Santiago
BHP Billiton, Escondida Cu mine, Antofagasta region
Freeport McMoran Chile, Santiago
AMEC, Santiago
El Teniente Cu mine, Rancagua
Chuquicamata Cu mine, Calama
Sociedad Química y Minera de Chile S.A.(SQM) Lithium brine operations, Salar de Atacama
US Embassy

Peru:

Ministry of Energy and Mines - Director of Mines and Mining Promotion, Lima
Ministry of Energy and Mines - Director of Mining Environmental Affairs, Lima
Duke Energy International (DEI), Lima
Freeport McMoran Peru, Lima
National Society for Mining, Petroleum and Energy - SNMPE **(**Sociedad Nacional de Minería, Petróleo y Energía)
Ferreyros (Caterpillar Distributor), Lima
US Embassy, Lima

ORGANIZATION REPRESENTATIVES VISITING THE STRATEGIC MATERIALS SEMINAR

DLA Strategic Materials (National Defense Stockpile)
Office of the Undersecretary of Defense for Science and Technology
US Geological Survey National Minerals Information Center
Hedrick Consultants, Inc.
Committee on Foreign Investment in the United States (CFIUS) team, Global Security Affairs, Assessments Branch of the Defense Technology Security Administration (DTSA) Policy Directorate
Office of Industrial Base Policy, Office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy
Senior Analyst, Office of the Director of Defense Procurement and Acquisition Policy, Program Acquisition and International Contracting, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics
Materials Manufacturing and Prototype Technology, US Army Armament and Research Development and Engineering Center (ARDEC), Picatinny Arsenal, New Jersey
Office of Technology Transition, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics
Office of Policy and International Affairs, U.S. Department of Energy
National Mining Association
Office of the US Trade Representative
Center For Hemispheric Defense Studies, National Defense University

CHAPTER I: INTRODUCTION

The question of government intervention in private markets to secure the materials necessary for national security is not new. In a debate over a government charter for a copper mine, Thomas Jefferson highlighted the difficulty of balancing security needs and federal overreach by paraphrasing a popular lyric in mocking his Federalists opponents: "Congress are (sic) authorized to defend the nation. Ships are necessary for defense; copper is necessary for ships; mines, necessary for copper; a company necessary to work the mines; and who can doubt this reasoning?" [1] During the Korean War, President Truman attempted to federalize steel mills to prevent a strike and assure continued availability of industrial assets in support of the War effort; however, he was thwarted by the Supreme Court. Today, policymakers are faced with the same essential dilemma as were Jefferson and Truman: there remains a disconnect between the government's need to consciously manage the supply of strategic materials and the need to rely upon the "invisible hand of the markets" to satisfy those strategic materials needs.

Scope and Approach

This paper examines the health of the materials industry and its capacity to support current and projected future national security requirements. Where market forces do not adequately manage risk in meeting those requirements, the paper assesses government policies to assure adequate material supplies. Finally, the paper proposes a framework to strengthen the government's ability to manage strategic material risk.

Unless defined in context to have a different meaning, the following terms are defined for use in this paper as follows:

- "Materials" is a general term for a mass of matter. However, the focus in this paper is on a restricted set of non-fuel materials, *strategic materials.* According to the FY 11 National Defense Authorization Act, strategic materials are non-fuel materials (A) upon which the production or sustainment of military (or other national security) equipment is dependent; and (B) the supply of which could be restricted by actions or events outside the control of the Government of the United States.

- "Military (or other national security) equipment" means equipment used directly by the armed forces (or other US Governmental agents) to carry out military (or other national security) operations.

- "Secure supply," with respect to a materials, means the "availability of a source or sources for the material, including the full supply chain for the material and components containing the material."[2]

- With respect to "materials industry," there is no single industry that provides material for national security purposes per se. When this paper refers to the "Materials Industry" or "Minerals Industry" or "Metals Industry" or like words, the reference is to the collection of companies or parts of companies that mine, refine, process, manufacture, or manage one or more materials that are used for national security purposes.

The team focused its attention on materials that directly relate to national security needs. Accordingly, the team did not examine in any detail the broader issues associated with materials necessary to maintain the vitality of the nation's economy or the narrower issues associated with materials necessary for other specific sectors or purposes.[3] The team selected a suite of six materials, or categories of materials, to serve as illustrative examples in order both to frame and assess both the current state of strategic materials policy and to recommend a new framework capable of mitigating shortfalls that impact national security. These materials or categories of materials include five that are likely candidates to be considered as strategic materials (beryllium, rare earth elements, titanium, lithium, and superalloys). The team also studied extraction and processing in Chile and Peru. Copper is an example of a material that is not normally considered a strategic material, but could become strategic in the event of geopolitical changes.

Overview and Recommendations

Strategic materials markets possess characteristics that can increase risk to national security needs. The good news is there are no known materials whose availability is sufficiently unreliable such that there is an immediate crisis that threatens near-term national security requirements. The bad news is that we have had recent issues (beryllium and rare earth elements are examples) in which US policy provisions have proven to have marginal utility in resolving potential supply-demand mismatches. The worse news is that the current set of policy provisions does not appear to be adequate to prevent future material imbalances from arising that would cause national security requirements to be unsatisfied.

The concern within the United States government and commercial sectors focuses on the potential fragility of material supply chains, particularly for those materials where the United States faces import dependency and where no or limited substitutes exist for the material in question. In the year 2000, the United States relied on imports for 16 of these materials. In 2010, the number was 24.[4] In general, the firms that provide strategic materials for national security provide the same or similar materials to commercial users. Furthermore, commercial demands generally dominate, as is the case for titanium materials supplied to the aircraft industry.[5]

The current set of material policies could be described as a "patchwork" approach; however, this term incorrectly implies that all of the patches somehow result in one piece of fabric that fulfills a purpose, which is not the case. Instead, the patchwork evolved over time to address specific, localized issues. What is required is a whole-of-government approach to strategic materials management that allows each department to fulfill its objectives and to integrate strategies across the US government. The White House recently took a step in this direction in December 2010 by establishing an inter-agency subcommittee on mineral supply chains. This committee will "facilitate a strong, coordinated effort across federal agencies to identify and address important policy implications arising from strategic minerals supply issues."[6] Its membership includes 14 executive agencies, to include Defense, Energy, Commerce, State, and Interior, among others. It remains to be seen whether this committee will have the appropriate authority to influence policy, but direction and oversight from the White House is certainly a step in the right direction.

The fundamental policy recommendation in this report is that the US needs to build on recent efforts to establish interagency coordination by elevating the membership of the existing National Science and Technology Council subcommittee on strategic materials. This body would be charged with determining which materials are strategic on a risk-informed basis and then coordinating policies and actions to assure that potential shortfalls of strategic materials are mitigated to avoid adverse impacts to national security. The risk-informed processes would include actions to address the core strategic materials management policies as well as the shaping and hedging mechanisms we need to assure that policies are timely and reflective of emergent low probability-high consequence considerations.

The team's research in Peru and Chile, where national mining and related policies have had unmistakable impact in adding significantly to the prosperity of these emergent countries, supports the conclusion that coordinated materials management policies can support meeting achieving national objectives—a result which the US would do well to emulate.

CHAPTER II: STRATEGIC MATERIALS AND MARKETS

The fundamental questions government policymakers must answer when addressing strategic materials issues are whether intervention is required and, if so, how. These would be risk-informed questions. *Risk is the probability of a materials supply disruption event combined with the consequences of the disruption.* In applying the risk concepts to strategic materials, an analyst is limited to considering risk in notional ways since neither probability of a material disruption nor its consequences would be precisely measurable. This chapter analyzes how market attributes translate into risks to national security.

This chapter identifies what market factors lead to risk to national security, what structural market factors define the strategic materials industries, and how the strategic materials markets are structured. The risks arise from possible disruptions due to supply limitations, cost considerations, and inability to develop substitutions. The market factors that define the industry include high barriers to entry, long investment horizons, and the dominance of commercial over national security demands. Taken together, these factors combine to create material supply markets that respond slowly or not at all to changes in national security demand. The strategic materials industry structures vary from commodity-based markets to monopsonies, depending on the details of the specific material.

Market Risk Model

This team is not the first to approach the strategic materials issue from a perspective of risk. In their study *Minerals, Critical Minerals, and the US Economy*, the National Research Council (NRC) proposed a two-axis risk matrix that captured supply risk and impact of supply restriction.[7] The Department of Energy, in developing a strategy for materials used in clean energy technologies, built on the NRC's work by adding short- and medium-term criticality to their analysis.[8] Neither addressed the risk associated with either high costs or cost volatility, which the team believes is a critical component to assessing tradeoffs in potential strategies. The team considers that risk to supply of strategic materials for national security purposes arises from one or more of the following factors:

- ***Supply:*** This factor addresses the extent to which the US can rely on a supply of a particular material in sufficient quantity and with sufficient quality to meet current and anticipated national security needs.

- ***Cost:*** This factor addresses whether the cost (both absolute cost and cost volatility) of obtaining the required quantity and quality of a particular material is in line with the *benefits* accrued to national security needs.
- ***Impact on National Security:*** This factor addresses the degree to which national security needs are impacted by limitations on the supply of a particular material.

Structural Factors

The team considers the following factors to be the attributes to be most relevant to characterize the behavior and performance of the strategic materials industries.

Barriers to Entry

Markets involving strategic materials include the extraction and refining industries as well as manufacturing industries that employ strategic materials as inputs. The barriers to entry in these markets consist of high startup and operating costs as well as significant legal, technical, and bureaucratic hurdles. For example, capital investment in the billions of dollars can be required to discover a mineral resource, acquire the mining rights and other legal or bureaucratic permissions, and establish an extraction capability. Annual operating costs for major mining operations such as the Henderson Molybdenum Mine in Colorado or the Escondida Copper Mine in Chile run to the hundreds of millions of dollars.

Delayed Return on Investment

In addition to the significant barriers to entry, the firms involved with strategic material extraction and related industries confront an extended wait before realizing a profitable return on their investments. With respect to the mining / extraction industry, it takes an average of 10 to 15 years before operations commence and the first ore or other products begin to flow into downstream refining or processing industries. The refining and processing industries face additional delays before product reaches market and financial returns materialize. Rare Earth Elements (REEs) represent an extreme example of the processing timelines It is very costly and difficult to extract them from the ores, and there is usually some radioactive thorium that is a byproduct of the extraction process. The production process takes ore from a mine, crushes it, mills it to silt, floats out the desired minerals, separates the desired oxides through highly selective chemical processes, and then produces pure metal from the oxides.[9] Recognized Australian REE expert Dudley Kingsnorth notes that the process must be tailored to each specific REE ore body, is capital intensive, and takes 2 to 3 years to establish the chemical separation capability for REEs (a duration distinct from the 10-15 year lead time to begin extraction).

Commercially-Driven Demand

The implication of increasing global demand for materials on the ability of the Department of Defense to develop and procure weapon systems deserves consideration. First, unless the increasing demand is met with a concurrent increase in supply or the introduction of substitute materials, the cost of these inputs will rise and cause an associated cost increase in the final products. Second, and probably more important, is the relationship between the national security sector as a market for these materials and other commercial markets that consume them. While there was a time where national security needs drove market demand and its precursor

R&D efforts for aerospace, computers, telecommunications and related technologies, that day has long since passed. The commercial sector dominates overall demand for every strategic material, except high purity beryllium metal. This is as true for commercial aerospace's dominance of the titanium market as it is for the automotive and food packaging industries' dominance of the aluminum market.[10]

The dominance of the commercial markets for strategic materials shapes the direction of the R&D efforts undertaken by strategic material producers. The small market share and associated profits associated with defense and national security consumption limits the incentives for firms to invest their own funding in defense related R&D. Consequently, the federal government, including the DoD, will need to rely on publicly funding R&D efforts for those technologies when the use will be primarily military. Incentives for commercial firms to cooperate in such research activities where the prospects for commercial applications are low.

Strategic Material Markets

The first important observation is that a single market for materials does not exist. At a minimum, there is a separate market for each material, such as titanium, beryllium, or copper. In many cases, a single strategic material will feed into multiple markets. For example, the beryllium mining and refining industry feeds markets for high purity beryllium and for lesser purity beryllium and these markets possess different supply and demand characteristics. Supply and demand functions exist for every market, regardless of each individual market's idiosyncrasies. Table 1 below provides a high level overview of the supply and demand characteristics of six materials. This information is illustrative only and does not represent a comprehensive analysis of the entire gamut of strategic materials or of the individual material markets. What the table reveals is that the market conditions can vary widely from material-to-material, and, accordingly, that policy actions for materials must be made on a case basis, rather than on a categorical basis.

Table 1. Market Structure of Six Prospective Strategic Materials

Material	Market Structure
Beryllium	**Supply structure:** Monopoly for High Purity Beryllium (HPB) **Supply elasticity:** Low. **Demand structure:** Monopsony for HPB. Broad market for other beryllium. **Defense segment:** USG is sole customer for HPB. **Demand elasticity:** For HPB: Inelastic demand. No viable substitutes for specific applications. For other Be products: Substitutes for lower purity beryllium given performance and cost trade space.
Copper	**Supply structure:** Oligopoly. **Supply elasticity:** Moderate. Mining and smelting operations can be scaled in response to changes in demand. **Demand structure:** Commodity market **Defense segment:** Small relative to non-defense market. **Demand elasticity:** Moderate. Alternate materials exist for most uses, albeit typically at a higher price point and with degraded performance.

Material	Market Structure
Lithium	**Supply structure:** Oligopoly **Supply elasticity:** Moderate to High. Li extraction and refining scales more quickly than most other materials. **Demand structure:** Demand driven by Li battery market. **Defense segment:** Small **Demand elasticity:** Moderate. Less efficient or effective materials currently available for batteries.
Rare Earth Elements (REEs)	**Supply structure:** Monopoly in the near term, shifting to oligopoly within 5 years. **Supply elasticity:** Low. China only current major producer. Supply elasticity may increase over time as Mountain Pass and other sources come on-line. **Demand structure:** High demand across a large number of intermediate and final products. **Defense segment:** Small demand but critical usages. Demand also varies with each specific element. **Demand elasticity:** Highly inelastic. Few viable substitutes that do not present significant performance trade-offs.
Superalloys	**Supply structure:** Oligopoly. **Supply elasticity:** Low to moderate. Additional capacity is slow to develop. **Demand structure:** Small number of high-volume buyers for superalloys. **Defense segment:** Small demand but critical usages. **Demand elasticity:** Inelastic demand since substitutes not readily available.
Titanium Metal	**Supply structure:** Oligopoly dominated by a small number of global producers **Supply elasticity:** Very low for specific aerospace applications **Demand structure:** Demand driven by cyclical aerospace orders and heavily affected by industrial users. **Defense segment:** Small compared to commercial demand. **Demand elasticity:** Inelastic since aircraft manufacturers willing to pay premium prices to gain performance benefits of titanium.

General Supply Considerations

Demand for materials has grown significantly over the last two decades. The projected increase in global demand for critical materials obviously generates concerns about the adequacy of supplies and the potential fragility of the end-to-end supply chain. "[R]ather than focusing on running out of minerals, it is more useful to consider the constraints imposed on emerging technologies by the costs, geographic locations, and time frames associated with mineral production."[11] The concern within the United States government and commercial sectors focuses on the potential fragility of the supply chain, particularly for those strategic materials where the United States faces import dependency and where no or limited substitutes exist for the material in question. In the short- to medium-term (one to ten years), supply risks are determined by the characteristics of existing sources of supply or new facilities that are sufficiently far along that they are reasonably certain of coming into production within a few years.[12] When the time horizon extends beyond a decade into the realm of long-term considerations, Dr. Rod Eggert notes that "mineral availability is largely a function of geologic, technical, and environmental factors."[13]

Market Concentration and Risk

Risk due to concentration in the strategic materials supply chain is not limited to the relationship between primary material producers and consumers. In 2006, mining companies in Chile and Peru experienced a major shortage of the specialized tires required to equip their 330+ ton earth-movers. As there are only a few tire manufacturers that can make these enormous tires, the companies faced a significant risk of curtailed operations.

Indeed, there are potentially many areas in which inputs result in critical paths, including water and energy. These "for the want of a nail, the war was lost" scenarios highlight the fact that material supply chains are vulnerable at many points. Analysts must be attuned to the risks associated with ownership and geographic concentration in supply chains.

Strategic Materials Markets: Supply Structures. The markets for strategic materials on the supply side broadly consist of a cluster of major producers for each of the materials. In addition, the extraction and refining industries have undergone a high degree of consolidation over the past several years. As a result, most of the materials markets resemble oligopolies in which a small number of very large firms dominate the competitive landscape (high-purity beryllium represents the only monopoly in the group of materials considered for this analysis). The mining and refining industries are also generally considered very mature industries where the remaining firms compete on the basis of price and the key to long-term value generation rests with producing at a lower cost. Innovation tends to occur with respect to the processes used to produce the materials rather than in terms of new products introduced into the market.

Geopolitical Concerns

Materials extraction is sensitive to geopolitical conditions. For example, the upcoming Presidential election in Peru has created a great deal of uncertainty in the country's mining industry. Despite a legal regime that promises regulatory and tax stability, the public statements of the candidates have led mining companies to postpone exploration and expansion investments. Analysts must account for geopolitical uncertainty when assessing supply risk.

The use of Rare Earth Elements constitutes one of the exceptions to this broad observation about the maturity of the industries and the focus of innovation. US-based Molycorp developed a new water filtration product, XSORBX®, which is made from cerium. Because previous commercial demand for cerium was low in terms of tonnage (its primary application, glass polishing, does not require large quantities), a high-cerium ore body like Molycorp's Mountain Pass mine would produce a great deal of non-sellable material. Molycorp anticipates that XSORBX® could eventually absorb all of its cerium production.[14]

The risk to the supply of titanium comes primarily from titanium's combination of high price and price volatility. These price challenges have not just caused the DoD difficulties in acquiring the systems that use titanium; they have significantly dissuaded the DoD from more widespread use of titanium. Because national security requirements represent such a small portion of overall titanium demand, the market does not respond to DoD calls to produce less-expensive non-premium materials for use in armor and shipbuilding applications.

Strategic Material Markets: Supply Elasticity. Lithium represents perhaps the greatest level of supply elasticity of the materials considered by the group. There are a limited number of suppliers of concentrated lithium solutions, with the Chilean company Sociedad Química y Minera de Chile S.A. (SQM) standing out as the largest. According to SQM, the extraction techniques and technologies employed for lithium via brine solutions can scale up production in a matter of months, as opposed to years that characterize hard rock mining activities.

For some materials, recycling is an economic result of the generally low degree of supply elasticity that characterizes the materials markets, although the difficulty and cost of recycling varies greatly from one material to the next. Copper and titanium, for instance, are easily and economically recycled in some applications. One of the titanium plants visited by the team received the majority, if not all, of its titanium from recycled materials. In contrast, REEs are very difficult to recycle due to the complexities and environmental issues associated with separating them from the end use products, such as microelectronics and permanent magnets.

General Demand Considerations

The demand functions for strategic materials vary to a much greater degree than the supply function in these markets. In particular, there are a broad array of consumers that employ these materials in the manufacture of many different types of intermediate and end products. Molybdenum, for instance, is used in a 99 percent pure product as an additive to alloys and as a 96 percent pure product in dry lubricants. Both of these markets boast multiple manufacturers that create a broad base for demand.

High purity beryllium represents a very different set of demand characteristics. While there are commercial applications for this material, the vast majority of demand is for national security applications. Without national security demand, there is not sufficient commercial demand to support the existence of a US manufacturer. As discussed in the appendix, this led to a direct government investment in Materion, the only US producer of high-purity beryllium.

Copper, on the other hand, is clearly a commodity item on the demand side. The number of uses for copper and the number of firms involved in intermediate and end product manufacturing are essentially unbounded. Global prices fluctuate as a result of both supply and demand dynamics, with demand playing the dominant role in recent years as seen in both the global economic recession and subsequent recovery.

Strategic Material Markets: Demand Elasticity. Demand elasticity generally results from the availability of substitutes for the material in question. The unique properties of many of the materials examined in this effort, such as high strength-to-weight ratio or high degrees of temperature or corrosion resistance, make them unlikely candidates to be displaced by substitution. The trade-off decisions that consumers of these materials confront involve accepting a lower level of performance with a substitute material in order to mitigate a supply driven issue, such as uncertainty of supply, high price points, or volatile price points.

Titanium represents an excellent example of a low degree of demand elasticity, particularly for specific aerospace and defense applications. With its high strength, low weight, and corrosion resistance, titanium is essential in both the structural and engine components of military aircraft such as the F-22 and the F-35. Additionally, it is a valuable performance enhancing ingredient in a variety of ground weapon systems from artillery to armor. Coupled with its market characteristics, the material properties of titanium establish it as a candidate to be identified as a strategic material.

Overall Assessment

In general, free markets have operated to meet the nation's needs for materials for national security. However, the materials industries are subject to market forces that have caused increased risks to the nation's ability to meet national security requirements; recent examples include beryllium, rare earths, and titanium. As with other public goods, if market forces alone are insufficient to deliver what the nation needs, government intervention may be warranted. The next chapter discusses policy matters affect--positively and negatively-- the assurance of adequate supplies of strategic materials when market forces might be deemed to be insufficiently robust to meet national security needs.

CHAPTER III: POLICY

The US Government has, over the decades, enacted a series of laws, regulations, and policies that affect real and perceived issues with the free market's ability to provide strategic materials for national security at acceptable levels of risk. Some of these apply broadly across several segments of the strategic materials industry, while others are focused on specific materials or activities. This chapter describes those laws, regulations, and policies most relevant to today's strategic materials industries, and assesses their effectiveness both individually and as a whole.

> **Whole-of-Government Approach**
>
> Chile, a nation reliant upon its abundant mineral resources for economic security, provides an example of the power of a strategically-focused whole-of-government approach to materials. Starting with the strategic priority of maximizing national gains from the extraction of resources, Chile has aligned the structure and actions of multiple ministries to successfully manage materials production, even to the extent of enshrining materials extraction language in its constitution. For example, to obviate inherent conflicts between sustainability and short-term economic gains in the permitting process, Chile redistributed environmental management responsibilities between the Ministries of Mining and Environment. Chile also invests in attracting foreign mining investment, guaranteeing legal and financial stability to reduce risks to private firms. Peru appears to be pursuing a similar whole-of-government approach.
>
> While the US faces a different balance point between strategic imperatives than Chile (e.g. managing supply risk versus maximizing production gains), integrating the efforts of multiple agencies around a common strategic plan promises to improve the effectiveness of government efforts to manage strategic materials risk.

General

One of the most specific and comprehensive statutes concerning strategic materials is the Materials and Mineral Policy and Research and Development Act of 1980. It sought to "promote an adequate and stable supply of materials necessary to maintain national security, economic well-being and industrial production."[15] It specified a requirement to balance economic and security needs with environmental and natural resource constraints. It also directed the President to identify critical material needs, establish federal materials programs, conduct long-range assessments, promote research and private enterprise, implement interagency coordination processes, and leverage government resources to make materials available for critical needs.[16]

Despite the intentions of the law, it appears not to have been implemented. The team attributes this failure, in part, to the fact that federal agencies find themselves operating in a reactive manner, responding to crises after the fact, instead of anticipating actions to lessen the impact of material shortages. Additionally, despite direction to establish interagency coordination processes, this law has failed to ensure cooperation between federal agencies. In fact, federal actions occasionally have contradictory impacts. For example, the Department of Energy has its own strategy for critical materials, which has a distinctly commercial focus. Whereas the DoD and DOE materials management processes have different goals and different terminology, their scopes do overlap in some areas; yet, even for these common areas, there is little evidence of interagency cooperation.[17] For a national strategic materials strategy to be effective, it must be coordinated across the federal bureaucracy.

Extraction

In order to promote exploration and exploitation of the mineral resources in the Western US, the government enacted the General Mining Act of 1872.[18] This law established procedures for individual miners and mining companies to establish claims to mineral resources *on public lands* with limited fees and regulation. The law also provided a means for individuals and companies to establish property rights for the mineral resources. Today, roughly one-third of the United States is public land, but half of those public lands are closed to mining and resource exploration.[19]

While this 139 year old policy regime does not deter mining investment per se, it also does not incentivize exploration and development, nor does it capitalize on opportunities for the government to capture revenues accrued from the extraction of what is arguably a common resource held by the public. Congress has made several attempts to reform the Mining Act, all of which have failed due to partisan and state interests, disagreements over percentages of federal royalties, environmental and reclamation standards and air and water quality standards.

Environment

Environmental considerations were not a priority in the early days of the republic. There was a general lack of awareness of the environmental impacts of mining on public health and welfare to include the environmental impact on air and water quality and the impact on fish and wildlife in the vicinity of active mines. Additionally, after mining was completed, the general practice of the era called for miners to abandon their mines leaving behind dangerous structures, safety hazards and contaminated land and water.[20] The 1969 National Environmental Policy Act (NEPA) greatly expanded the federal government's oversight of environmental issues.[21] To address the problem of abandoned mines, the government enacted the 1977 Surface Mining Control and Reclamation Act (SMCRA), making it mandatory for miners and corporations to comply with environmental standards during the life of the mine and during shutdown operations.[22] As part of the permitting process, mine operators must post a bond that provides surety of funds available for reclamation.

While mine operators must comply with the SMCRA, NEPA, Clean Air and Water Act, and the Toxic Substance Control Act, the federal government has largely deferred environmental regulation of the mining industry to individual states with mining operations – all with varying degrees of standards and laws. According to the Environmental Law Institute, the most important policy governing mining in each of the states is not from federal or state statutes but from the terms and conditions negotiated between the mine operator and the individual state.[23]

Industry representatives state that compliance with environmental standards is not a significant limitation on their ability to operate. Indeed, good environmental stewardship is a strategic imperative for mining companies, as it builds goodwill with the community. However, the process for obtaining permits is viewed as overly burdensome, time-consuming, and unpredictable, and, when compared to processes of other countries, serves as a comparative disadvantage for US mining operations.[24] Streamlining the environmental permitting process and enhancing its predictability would reduce a significant barrier to entry for domestic resource extraction.

National Security Applications

In addition to laws and regulations pertaining to the production of strategic materials, there are several laws that govern their use in national security applications. These include the Specialty Metal Provision (SMP) in the NDAA (formerly associated with the Berry Amendment), the Defense Production Act, and the National Defense Stockpile.

Berry Amendment and SMP

The Berry Amendment restricts the DoD from acquiring a list of items including food, clothing, fabrics, and certain tools that are not produced in the United States. Originally part of the Berry Amendment, the SMP directs 100% domestic sourcing for a specific set of metals and alloys.[25] The legislation was intended to protect US industry, ensure domestic sources for specialty metals, and provide US forces with US-sourced equipment. Dependency on foreign sources has the potential to put DoD capability at risk, as supply of these metals could be constrained for a variety of reasons including instability in the source country or the source country imposing supply restriction in protest of US policy.

The SMP has six significant deficiencies. First, the criteria to define specialty metals within the policy are not reviewed and updated, which causes materials to be retained as specialty metals that no longer warrant the moniker (e.g. some alloy steels), and excludes other materials not previously identified that now warrant being considered specialty metals (e.g. rhenium). Second, for US manufacturers of defense goods, the SMP does not distinguish between friendly and unfriendly nations as sources of specialty metals—it prohibits all foreign sourcing. Third, foreign end item manufacturers of defense goods in "qualifying countries" receive an unfair advantage over US manufacturers because they are not bound by the SMP. Fourth, the SMP does not address the growing complexity of supply chains. In the global supply chains, the ability of suppliers to track metal sourcing down to the component and part level is becoming increasingly difficult. Fifth, when a specialty metal is simply not available from domestic sources, procedures for securing waivers are cumbersome, again putting US defense manufacturers at a disadvantage. Finally, since national security demand represents a small portion of overall specialty metal demand, the firms that are "protected" by the SMP actually succeed or fail based on their ability to compete in commercial markets. In other words, the SMP does not actually serve to protect the firms it purports to protect.

Defense Production Act (DPA)

The DPA consists of three current authorizations. Under Title I, the Defense Priorities and Allocations System (DPAS) establishes priority ratings to vendors for production priority over non-rated orders.[26] It allows the Departments of Commerce and Defense to give higher priority to designated defense contracts, effectively moving them to the top of the queue ahead of commercial-sector orders.[27] Title III authorizes DoD to create assured, affordable, and commercially-viable production capabilities and capacities for items essential for national defense. Finally, the DPA is the authorizing legislation for the Committee on Foreign Investment in the U.S. (CFIUS),[28] which allows the President to block the acquisitions, mergers, and divestitures of US companies by foreign nationals when national security issues dictate.[29]

The DPA has provided vital support to the United States military in every conflict since it was enacted in 1950.[30] Among all the policy tools, DPA offers policy makers the closest thing to a "scalpel" like approach to strategic materials supply assurance. For example, DoD used the DPAS to prioritize titanium production to support armor requirements for the Iraq surge. Another example is the DoD's $90M investment in beryllium processing at Materion Corp. (formerly Brush Wellman) to address a situation in which national security requirements alone were not enough to maintain supply assurance (see the appendix for details of this case). Finally, in a case where the government arguably failed to properly apply the policy tools at its disposal, CFIUS allowed the Chinese acquisition of US high-performance magnet maker Magnequench, resulting in the loss of a pioneer US rare earth magnet maker.[31]

National Defense Stockpile

The US national defense stockpile was initiated under the 1939 Strategic Minerals Act to "minimize vulnerability to a wartime shortage of imported raw materials."[32] At the time, a materials policy commission determined that stockpiling was the most cost-effective option to manage risk. The purpose of the existing defense stockpile is to respond to military conflict scenarios used by DoD for planning and budgeting, containing materials necessary to reconstitute munitions, combat support items and weapons systems within three years after a conflict.

Over the years, stockpiling has proven to be ineffective.[33] In its lengthy history, there have been very few examples when the stockpile was used for its intended purpose. Additionally, because new legislation is required every time a material is to be added or removed from the stockpile, NDS managers do not have the flexibility to adapt to rapidly changing defense needs. Congress decided to sell off much of its material in the mid-1990s because it determined that the materials in the stockpile were no longer needed. The stockpile had become a symbol of yesterday's global war footing and not representative of a globalized world connected by extensive supply chains and express transportation.[34] According to the Defense Logistics Agency (DLA), the National Defense Stockpile "continues to reduce its inventory of strategic and critical materials and has not transitioned to the growing concern over rapidly changing world market conditions…"[35] In August 2010, DLA proposed changing the NDS to the Strategic Materials Security Program. Under this new construct, DLA would apply modern supply chain management techniques to increase assurance of strategic material supply. In some instances stockpiling would be the tool of choice; in others, source diversification or other risk mitigation measures would be applied. Legislative action on this proposal has been postponed to the FY 13 NDAA. In the meantime, DLA is working with the Congress to gain authority to purchase and release materials from the existing stockpile without requiring new legislation.[36]

Strategic Materials Protection Board

The 2007 NDAA directed the DoD to establish a Strategic Materials Protection Board (SMPB) with the mandate of assessing the need for and risk associated with "materials designated as critical to national security;" developing a strategy for ensuring secure supplies of these materials; providing recommendations to strengthen the industrial base for materials; and publishing a list of recommendations and specialty metals at least biennially.[37] The SMPB did in fact meet and develop a list of recommendations, which included an integrated materials list of 128 materials identified by various elements of the DoD as being of interest.[38]

The main shortcoming of the SMPB's efforts is not in its charter or the outcome of its work, but rather in the composition of the SMPB itself. Interagency partners were included in the analysis, but at the working group level, not as principal decision-makers. This limited the effectiveness of the SMPB's strategy by confining it to actions within the purview of the DoD. Furthermore, the SMPB's reports do not specify any strategies for the President's consideration; just that such strategies will be provided in the future.

> **China and Rare Earth Elements**
>
> China started its REE strategy in the 1980s, taking advantage of its mineral resources to become the low cost producer of REEs and drive other competitors from the market. China created major programs and laboratories to further technological breakthroughs through R&D. China also purchased Magnaquench, a U.S. pioneer in RE permanent magnets, in 1997 and moved the entire operation back to China in 2002. By 2007, China had become a leader in the permanent magnet market with 130 magnet manufacturing enterprises and 80,000 tons of annual magnet production.
>
> During the last six years, China's strategy has evolved somewhat. There have been attempts to purchase the most promising global RE reserves in both Mountain Pass, CA and Mt. Weld, Australia. China has begun restricting its export quotas between 5% and 40% per year while also adding additional taxes, causing major global price increases. China also encourages foreign companies to move REE end product production to China as a way to ensure a steady resource supply.

International Trade Provisions

Due to the global nature of strategic materials markets, US and foreign trade policies play a significant role in shaping strategic material risk. The US encourages free trade, as fair competition among international strategic materials manufacturers improves product value. However, lack of diverse sources for strategic materials can increase risk due to geopolitical uncertainty. Additionally, unfair trade practices by foreign countries can drive domestic and allied producers out of business, securing artificial monopoly positions which can be leveraged for strategic advantage. The US has several tools with which it can manage international trade, including tariffs, trade agreements, and export controls. While they have not been extensively employed to address strategic materials issues in the past, they remain potential levers for policymaker consideration.

Tariffs and Duties

Tariffs can serve to protect domestic industries by altering the conditions under which goods compete. Tariffs alter these conditions by putting competitive imports at a price disadvantage.[39] A statute that essentially serves the purpose of a tariff is the Trade Expansion

Act of 1962, which allows the Department of Commerce, with input from the DoD, to recommend that the President adjust imports for national security purposes.[40] Presumably this could be done to protect a critical industry that is being threatened by a cheaper foreign supplier.

It can be argued that, while tariffs may help certain U.S. companies stay solvent in the short term, the free market provides better long term remedies. The question is whether or not the tariff is being applied in reaction to unfair market pressures or to simply protect an inefficient and uncompetitive firm. If the market pressures are fair and the supply sources are deemed to be of low risk, then tariff protections merely increase the cost of material input without benefit to supply assurance. There is little evidence that the political forces that support US tariffs have been applied with a proper market and risk assessment.

Trade Agreements

The US Trade Representative (USTR) monitors trading partners' implementation of trade agreements with the US, enforces America's rights under those agreements, and negotiates and signs trade agreements that advance the President's trade policy.[41] The US is a member of the World Trade Organization (WTO), which governs trade among its 154 members. In addition to membership in the WTO, the US has free trade agreements (FTAs) with 17 countries. In addition, there are 21 DoD MOUs that require the signatories to remove barriers to procurement of defense supplies or waive their respective buy-national laws and regulations (e.g. Buy American Act and Berry Amendment), to the extent permitted by law, for covered defense procurements.[42] Free trade agreements normally are not limited to specific materials or products, and there are no strategic materials-specific trade agreements. That being said, the WTO provides exemptions to trade rules for national security purposes.

While trade agreements promote the free flow of goods among friendly nations and help economic development and prosperity between trading partners, they open US strategic materials producers to potentially unfair competition. The WTO provides mechanisms by which member nations can identify and seek remedies to unfair practices, but these mechanisms can take years to resolve, as has been the case with a WTO case against China revolving around nine material resources.[43] The US also has the ability to impose anti-dumping and countervailing duty remedies unilaterally, but these can have unintended consequences including shortages of supply, higher prices and lost jobs in other industries.[44] Sources of supply within a trade agreement should be determined low risk and in consonance with DoD requirements of supply assurance for strategic materials.

Export Restrictions

Export restrictions come in a multitude of forms. They include: quantitative export restrictions (quotas), export taxes, duties and charges and mandatory minimum export prices. The most common form of export restrictions used is export taxes or duties.[45] They are used by policy makers in response to a variety of social, economic and political objectives. These objectives include environmental protection and promotion of downstream industries, revenue maximization, and preservation of reserves for future use. Export restrictions are therefore sometimes in place in sectors where global reserves are sufficient to meet demand, but reserves in the specific country applying the measure is not.[46] This is particularly important when the US is a consumer of foreign materials for strategic purposes. The US does not currently have any export restrictions on minerals.[47] It should be noted however that the US does utilize two sets of export control laws that govern the export of both defense-related and commercial products. These are the International Traffic in Arms Regulations (ITAR) and the Export Administration Regulations respectively.[48]

There has been considerable debate throughout the defense industry that ITAR puts US companies at a strategic disadvantage in the global market place because it limits their potential worldwide customer base.[49] Titanium, beryllium and high performance magnet manufacturers have particularly strong feelings about this disadvantage.[50] The trend toward globalization increases the complexity of concurrently protecting critical US technology while promoting US exports. Certainly, there is a need for review and, again, substantiation of a "scalpel" like approach for the application of export restrictions. High walls should be erected around the technology of critical systems, but in most areas, US companies should be allowed to freely compete using their technical superiority as a comparative advantage.

Overall Assessment

The individual laws, regulations and policies discussed in this chapter vary greatly in their effectiveness in reducing strategic materials risk. Taken together, while they provide a wide range of options for policy intervention, there is no mechanism within the government that applies them synergistically in pursuit of a cohesive risk-informed strategy. Previous efforts, such as the Materials and Mineral Policy and Research and Development Act of 1980, directed a whole-of-government effort to address this lack of cohesion, but the team was unable to find any evidence that such an effort is in place today. In the next chapter, the team recommends a way forward that addresses this significant gap.

CHAPTER IV--RECOMMENDATION

The 2010 *National Security Strategy* states that "strengthening national capacity [requires a] whole of government approach."[51] Strategic materials supply chains, inherently complex and intertwined, are important to multiple departments and agencies in the executive branch. To properly manage strategic risk arising from supply, cost, and impact to national security, Congress and the executive branch should collaborate to establish an interagency committee with the capability and authority to conduct continuous strategic assessment, lead the development and implementation of coherent strategies and policies for addressing risk, and foster communication among the diverse stakeholders in the materials industry.

Interagency Committee

In December 2010, the National Science and Technology Council (NSTC) chartered the Critical and Strategic Mineral Supply Chain Sub-Committee of the Committee on Environment, Natural Resources, and Sustainability[52] to bring interagency coordination and focus to strategic materials policy. This sub-committee, however, lacks sufficient political power of its membership to effectively shape policy throughout the executive branch. What the team proposes here that is new is that the Sub-Committee should have a principals committee of the same name, with membership established at the level of assistant department secretary or deputy agency director level. The Principals Committee on Critical and Strategic Mineral Supply Chain would then be co-chaired by the Director of the Office of Science and Technology Policy and another cabinet-level official, preferably of one of the departments with important equity in strategic materials. Potential candidates to serve as co-chair include the secretaries of the departments of Energy, Defense, and Commerce. In order to strengthen the Principals Committee on Critical and Strategic Mineral Supply Chain, it should be established in legislation and chartered by executive order. The legislative foundation for the committee's work already exists in the Materials and Mineral Policy and Research and Development Act of 1980. The team believes that implementing the legislation by executive order–similar to the way in which the Committee on Foreign Investment in the United States (CFIUS) was established[53]--will bring the force of law to the effort, thereby strengthening the unity of effort needed to ensure successful strategy development and implementation. In particular, the authorities in the executive order need to be explicit in establishing accountability of the participants in the Principals Committee and provide sufficient authority to the co-chairs to enable the interagency committee to work effectively. Expressing proper authorities and responsibilities in the executive order will attempt to obviate the problems experienced before in having inadequately empowered officials.[54] In furtherance of the goal of maintaining vigilance from the interagency process, an annual report on the identity of and actions regarding strategic materials should be delivered to Congress and signed out at the political level.

Additionally, the Principals Committee on Critical and Strategic Mineral Supply Chain should have a permanent, dedicated interagency staff to carry out its day-to-day responsibilities. The staff would be responsible for administrative support, research, analysis, coordination, and communication. A permanent staff with the right expertise – economic, technical, and strategic – is a key enabler for both continuity and focus. This staff would not need to be large since many agencies in the USG are currently engaged in conducting strategic material analysis the resources needed to support this work are largely already available. This committee should also integrate industry and academia in its deliberative process as both groups have unique knowledge in the crafting of materials policy that can provide meaningful contributions.

Continuous Strategic Assessment

A primary job of the Principals Committee on Critical and Strategic Mineral Supply Chain will be to maintain a continuous assessment of the strategic implications of developments in materials. As this committee is responsible for strategic risk management, the organizing framework of the strategic assessment should be based on risk. The committee's permanent staff will conduct forward-looking assessments of materials risk in the near-, mid-, and long-term. These assessments should address the capabilities and viability of domestic material supply chains, developments in global materials markets, and current and projected national security needs. A market force-informed analysis, such as illustrated in Table 1, will capture the most important factors affecting risk. A key factor in the committee's analysis will be the projected growth of developing economies such as China, which will drive large increases in demand for materials such as copper to support development of infrastructure. Additionally, the committee should factor in the fact that "new technologies and engineered materials create the potential for rapid increases in demand for some element used previously and even now in relatively small quantities."[55]

As discussed in Chapter II, strategic materials risk arises from three sources: availability of supply, cost, and impact to national security needs. One of the Principals Committee on Critical and Strategic Mineral Supply Chain initial tasks is to formalize this risk model into an assessment framework that will allow for comparative analysis of risk. There are several approaches to risk assessment that the committee should leverage when developing its framework. The National Research Council's (NRC) Criticality Matrix focuses on availability and economic impact of supply restriction.[56] The Department of Energy's Criticality Matrix uses the same axes as the NRC matrix, but focuses on clean energy applications.[57] Additionally, the committee should also review tools in use by industry, which incorporate cost as a variable.

The Principals Committee on Critical and Strategic Mineral Supply Chain should present its assessments in a format that captures qualitative factors, such as is illustrated in Table 2 below. In each of the individual risk categories, analysts would qualitatively characterize the risk along with a brief description of the most relevant issues pertaining to that risk. The summary risk assessment depicts the holistic risk for that material and captures the urgency with which the nation should pursue mitigation strategies. Analysts would conduct separate assessments for short-, medium-, and long-term outlooks. The six example materials depicted in Table 2 span the gamut from minimal risk to areas of critical concern, and taken together illustrate how such a framework provides both analytic rigor and cogent communication.

Table 2 Example Strategic Material Risk Assessment Framework

	Risk Analysis			
	Supply	**Cost**	**Impact**	**Summary**
Rare Earths	At risk 95% dependence on Chinese supply until 2013	Concern Two- to five-fold increase in prices in the past year, depending on individual elements, but generally small portion of total application cost[58]	At risk Critical to weapon systems and green energy, no substitutes	At risk Critical until US capability on line in 2014, heavy REEs may remain critical in the years beyond
Beryllium	Concern Be is a critical material essential for national security. Current govt and Industry partnership (via DPA Title III) has assured a future supply for US and allied needs	Concern High cost of Be is well known to its exceptional characteristics compared to other materials. Supply shortages could disrupt market costs	At risk No known substitute for high purity Be	Concern Overall assessment is moderate due to criticality of Be and its uses and current US supply & availability
Superalloys	Minimal Broad supply chain for input elements, healthy US/allied production base	Concern High input price volatility, unknown Chinese demand/supply profile	At risk No substitutes for high-temperature turbine applications	Concern Monitor Chinese industry, no current case for action
Titanium	Concern Sufficient domestic supply of premium metal, but no major source for non-premium metal for non-aerospace applications	Concern High price and price volatility limits widespread usage in armor and naval systems	Concern Limited substitutes for aerospace structure and engine applications. Substitutes available for non-aerospace applications.	Concern Cost of premium metal prohibitive for non-aerospace use. Risk in aerospace due to high price and price volatility.

	Risk Analysis			
	Supply	**Cost**	**Impact**	**Summary**
	Concern	Minimal	Concern	Minimal
Lithium	Limited geological / geographic dispersion of supply. Primary supplier (Chile) is reliable trading partner.	Cost may rise as demand for lithium in green energy / mobile devices increases globally, however not at the point of concern as of yet	Light weight and energy density make substitutes significantly less attractive for defense applications	Continue R&D efforts into substitute materials for light weight battery applications
	Minimal	Minimal	Minimal	Minimal
Copper	Broad supply from both domestic and reliable international trading partners	Low price with some volatility. Price driven by demand in emerging markets such as China and India.	Substitutes available for many applications	No specific concern at this time

Strategy & Policy

The Principals Committee on Critical and Strategic Mineral Supply Chain must lead a collaborative interagency process that develops and coordinates strategy and supporting policy to address emerging material supply chain risks. The committee's approach should be methodical, explicitly proposing the desired *ends* for strategic material strategy, assessing the optimal *ways* to achieve the desired ends, and determining the *means* by which a coherent strategy may be implemented. A key outcome of this organization's work will be the early identification of potential risks, which will allow for earlier application of mitigation strategies at correspondingly lower costs. This section addresses the development and implementation of materials risk mitigation strategy.

Risk-Informed Strategic Planning

Some key questions that this interagency committee must resolve during the material strategy development process are: What is the particular risk and to whom? What degree of risk is imposed in both objective and subjective terms? What are acceptable levels and scope of costs to mitigate or reduce these risks? Who will bear the costs? And ultimately, should the US government or its partners intervene? One strategic framework that appears useful as a methodology for answering these questions is the Ascher / Overholt framework. Originally designed to assist in the formulation of national security strategy, Ascher / Overholt incorporates risk management as its key tenet, balancing the costs of risk mitigation against the impacts of the risk along three types of interests: core or existential risks, risks which require shaping of future scenarios, and risks which require hedging strategies.[59] Fundamental to this risk- and cost-informed framework for policy-making is the judgment of the Principals Committee on Critical and Strategic Mineral Supply Chain in determining how much cost we as a nation should bear in order to buy down risk to supply of strategic materials. As many strategic materials are supplied through fully functioning markets, implicit in this framework should be the assumption that all or nearly all policy interventions will come at the cost of a loss of market efficiency. Therefore, the option of *no action or intervention* should always be carefully considered as potentially the preferred policy.

Core strategy for enduring interests. The most compelling or existential risks to our nation's enduring national interests demand a core strategy that fully addresses those risks. As the mitigation of these risks is mandatory or nearly so, the costs of the policy actions are necessarily higher. The historical example of the use of beryllium metal during the Cold War serves as an illustration of material supporting an enduring interest and deserving of an associated core strategy. The United States faced a compelling existential threat: destruction during a nuclear attack by the Soviet Union. Pure beryllium served as a neutron reflector in nuclear weapons and a high-performance, dimensionally stable material for strategic weapons deliveries. In the context of that Cold War national security environment, the assurance of an adequate supply of beryllium was mandatory and drove correspondingly large investments.

Shaping strategy for broad national security interests. Shaping strategies include cost-effective policies designed to shape the future scenarios in a beneficial way, minimizing the impact of adverse scenarios while capitalizing on advantageous ones. The assurance of the significant majority of strategic materials will be supported by shaping strategies. For a strategic decision-makers serving on this committee, this means that the United States government should seek to design policies and invest in such a way as to shape future environments that affect the supply of these materials favorably to our interests, but in a cost effective way. By weighing the risk and degree of impact, they should be able to avoid expensive over-insurance against uncertainty for less than compelling threats. A strategy designed to support the development of commercial sources for non-aerospace quality titanium for armor and ship-building applications would fall into this category, as do most strategic materials research and development efforts that expand or strengthen the assurance of supply.

Hedging strategy for unlikely but high-impact events. Certain risks will be possible but unlikely, and a subset of these have adverse impacts so large as to require a hedge investment that limits damage, prevents catastrophe, buys time to adjust, or preserves opportunities for future actions. Like shaping strategies, these hedging strategies need to be cost-effective – essentially they are the "fire insurance" of strategic material supply. Beryllium, because of its use in nuclear weapons and strategic delivery systems, can be seen as an example of a strategic material deserving of a hedging strategy. The DoD's decision in 2005 to exercise DPA Title III to restart a domestic production source for high purity beryllium provided a hedge against being strategically surprised by a seemingly unlikely new nuclear arms race.

Policy Formulation

The broad assessment of risks as requiring core, shaping, or hedging responses will inform the selection of specific policy responses. As discussed in Chapter III, the individual agencies represented in the Principals Committee on Critical and Strategic Mineral Supply Chain already have a broad set of legislative and regulatory authorities with which to act, and, in most cases (especially for shaping strategies), those authorities should provide the tools needed to implement appropriate policy responses. A key benefit of this interagency approach is that these authorities can be applied in a synergistic fashion. For those strategies that suggest new authorities, this committee will lead efforts to advocate for legislative and regulatory action required to grant the authorities needed. This work must be done collaboratively with state-level governments, as they play a significant role in regulating firms in their states.

The Principals Committee on Critical and Strategic Mineral Supply Chain must also consider whether existing legislation and regulation should be changed even absent a specifically-identified risk. One of the committee's tasks should be a periodic review of the entire set of policies affecting strategic materials supply chains, looking for opportunities to streamline procedures and eliminate unnecessary limitations or barriers. Examples of policies that may be beneficial to review include the permitting processes for mineral exploration and operations, and the USG's comprehensive investments in STEM education.

Finally, the committee should look for opportunities to shape the nation's investment in this important industry. An example of this type of approach is research and development. China has made extensive investments in R&D in a broad range of strategic materials capabilities, leading the world in research in areas such as superalloys.[60] Recognizing that in many cases the source of comparative advantage for US strategic materials firms is their technological superiority, the committee should seek ways in which government, industry, and academia can partner to ensure that advantage continues into the future.

Strategic Communication

The Principals Committee on Critical and Strategic Mineral Supply Chain will also have a role in communicating US materials strategy to domestic and foreign audiences. With respect to domestic stakeholders, the committee will need to build support and advocacy for proposed policy actions with Congress, the executive branch, industry, and academia. This body can also provide a useful conduit for information sharing across the materials communities of interest, disseminating appropriate scientific, technical, and business knowledge to more quickly diffuse innovations across industry and the government. To foreign stakeholders, the Principals Committee on Critical and Strategic Mineral Supply Chain will communicate US intentions so that friendly foreign governments can develop cooperative strategies. With respect to foreign competitors, they should provide a clear and strategically coherent message in order to dissuade governments from pursuing strategies for achieving unfair dominance in materials markets through contravention of international norms and obligations.

Conclusion

The dependence of the security and defense of the United States upon the supply of strategic materials begs for a comprehensive framework capable of assessing and developing risk-informed and materials policies. The establishment of a Principals Committee on Critical and Strategic Mineral Supply Chain would provide such a framework, significantly better able to efficiently provide the required level of assurance for the supply of these materials. Additionally, this committee will provide a process to weigh the benefits of these policies against the costs in order to lessen the long-term burden on the nation and the US government. Consistent with the authority already provided in Title 30 of United States Code, the Executive Office of the President will then implement the policies developed by this committee through the cooperative actions of the member agencies and departments.

In 1955 President Eisenhower stated to Secretary of Defense Charles Wilson that "professional military competence and political statesmanship must join to form judgments as to the minimum defensive structure that should be supported by the nation. To do less than the minimum would expose the nation to the predatory purposes of potential enemies. On the other hand, to build excessively under the impulse of fear could, in the long run, defeat our purposes by damaging the growth of our economy and eventually forcing it into regimented controls."[61]

This message of balance was in keeping with his 1961 farewell address, in which he argued for "the need to maintain balance in and among national programs – balance between the private and the public economy, balance between the cost and hoped for advantages – balance between the clearly necessary and the comfortably desirable; balance between our essential requirements as a nation and the duties imposed by the nation upon the individual; balance between the actions of the moment and the national welfare of the future."[62]

The security of the United States deserves an executive branch body capable of striking just this balance for the supply of strategic materials—exactly what Jefferson, Truman, and Eisenhower each sought in his day.

APPENDIX: DPA TITLE III CASE STUDY

A well known modern day case study of the application of DPA Title III is the Brush Wellman Inc. (BWI) (now Materion) case, which dealt with the supply and availability of High Purity Beryllium (Be) - a strategic material.[63] In an effort to define whether a material was strategic, the National Research Council (NRC) produced a "criticality matrix" to evaluate a mineral's importance.[64] The matrix consists of a vertical and horizontal axis to assess the supply risk and impact of supply restrictions respectively. Be was designated by the criticality matrix as critical in terms of use and availability for three reasons. First, the markets most in need of High Purity Be metal are defense and aerospace system manufacturers. Secondly, there are no known substitutes for Be in products needed for national security. Third, there is a potential risk of supply disruption as will be highlighted in the BWI case.

BWI has provided nearly all of the domestic supply of high purity Be metal for more than 50 years. Prior to 1970, the U.S. was nearly 100% import dependent for its raw ore needs. In 1969, however, BWI opened a bertrandite mine, a beryllium ore, in Utah that provided a large, secure source of domestic raw material supply.[65] Nearly 30 years later, the U.S. exports nearly 80% of the world's production of high purity Be, as compared to China's exports of 15% of the world's production and Mozambique's 5%.[66] The U.S. is one of only three countries that processes beryllium ores and concentrates into beryllium products.

Be is an essential material for many defense, space, nuclear, and satellite applications where no other material can meet the performance characteristics provided by Be in these applications. For example, Be was used to correct the focusing on the Hubble,[67] build the optics on the Spitzer telescope[68], and the James Webb Space Telescope (JWST), which is scheduled to launch in 2014[69]. The JWST mirror segments were made from Be due to its light weight, stiffness, heat and cryogenic stability, and unique optical properties that make Be the only material of choice. These will be the largest mirrors ever to be launched into space.

Over the years, there have been many strategic programs[70] such as the Ballistic Missile Defense Program that have required infrared and optical sensors containing Be metal to detect and track missile threats. Other defense communications satellite programs depend on the availability of Be. The DoD relies on Be for the Defense Support Program (DSP) reconnaissance satellites, which are the principal component of the U.S. Satellite Early Warning System. These national assets are used to detect foreign missile launches, spacecraft launches, and nuclear explosions. DSP satellites were used during Desert Storm to detect the launches of Iraqi Scud missiles and provide timely warnings to civilians and military forces in Israel and Saudi Arabia.[71]

Clearly, the U.S. has depended on the use of Be for some of its most critical assets and military weapons for the past 60 years. Until 2000, there appeared to be a reliable domestic source of Be metal – BWI. But, in 2000 BWI mothballed[72] (engineered shutdown) its Be pebble plant in Elmore, Ohio, responding to environmental, health, and safety issues stemming from respiratory hazards associated with beryllium dust. After a comprehensive evaluation of their 50-year-old plant, BWI determined that an upgrade of the old plant was not technically feasible. After the shutdown, BWI relied on a limited supply of beryllium master alloy that it purchased from the Defense Logistics Agency's National Defense Stockpile (NDS). Other issues such as changes in U.S. policy on material stockpiling and other economic factors also contributed to BWI's decision to shut down the pebble plant.

During the same timeframe and without awareness of BWI's decision, DoD and Congress were looking into the criticality of strategic materials. Shortly after the Cold War ended, the U.S. determined that the stockpiling of strategic materials was not a priority due to the change in balance of global power. The NDS established quotas and began to sell off the stockpile of Be. In 1994, an independent analysis developed for DoD confirmed that there was no need to stockpile Be in the NDS. Later in 1995, DoD recommended to Congress that the NDS stockpile for Be should be sold off completely.[73] In 1996, DoD assessed the landscape once again and found there were no issues of assured access and availability of Be.[74] What DoD did not account for in this analysis nor anticipate was the independent decision by BWI four years later to close its Ohio pebble plant.

Fast forward to 2005 when the consequences of these independent streams of activity are now known. As directed by Congress in the FY2004 National Defense Authorization Act (sec 824), the DoD included a study in its Annual Industrial Capabilities Report that noted the U.S. had lost its only capacity to manufacture high purity Be metal in 2000. The report concluded that foreign dependence was not a viable option and that private investment was not likely to replace the BWI facility. As a result, the DPA Title III Beryllium supply industrial base project was established to meet essential national security requirements by ensuring a domestic production capability for Be metal.

The partnership between BWI and DoD began in late 2005 with an initial award of a $9 million contract under the DPA Title III Program to BWI (the project budget would later grow to over $100M). The project was to establish an uninterrupted supply of high purity Be metal for U.S. and allied defense and commercial markets. The project assumed construction of a new Be pebble plant in Elmore, OH. Construction began in 2007 and was completed in 2010 with production expected to begin in the fall of 2011. As of March 2011, the overall objective of the partnership between the Government and BWI has been met: a state of the art, safe, and viable production facility of high purity Be for the U.S. and its allies was built on U.S. soil.

Case Study Conclusions and Recommendations

Some would look at the BWI case and conclude that **more** government oversight and regulation of strategic materials producers would have prevented BWI's decision to mothball its r plant. The criticality of Be and the BWI case clearly presented a decisive opportunity where DPA Title III was able to shape the commercial market by investing in a partnership to produce what was needed. No other Government program focuses on developing production capabilities for high tech solutions as DPA does. But the BWI case also highlights that decisions by DoD are made with imperfect information caused by ambiguity and uncertainty[75] – in 1996, there was a stable, reliable, and domestic supply and capacity of Be, and, thus, the decision to reduce the stockpile was reasonable, given the information at hand. DPA Title III provides a "safety net" – a way to fix a critical technology necessity, strategic material or an industrial capacity shortage that will have real national security consequences, if allowed to continue.

Each year the DoD spends billions of dollars developing new technologies to advance U.S. capabilities;however, little is effort is expended to ensure these new technologies will remain viable into the future for critical defense needs. DPA Tile III steps in when industry cannot or will not invest in a technology or industrial capacity alone without Government assistance. There are enough checks and balances in DPA Title III's implementation approach to ensure its prudent and careful application and maintain transparency to the taxpayer and scrutiny from Congress. Today with 41 active projects, only .1% of all DPA Title III proposals have become actual projects.[76] Therefore, DPA Title III is a valuable component of the U.S. industrial policy tool chest to ensure the timely establishment, availability, supply, and domestic production capacity of critical materials or technologies required to assure our national security.

ENDNOTES

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[1] Letter from Thomas Jefferson to Edward Livingston in 1800 to deride the Federalists' sweeping interpretations of the Constitutions to provide vast spans of power to the new republic.
[2] *National Defense Authorization Act for FY 2011-05-23* , Section 829, signed on January 7, 2011. http://www.gpo.gov/fdsys/pkg/PLAW-111publ383/pdf/PLAW-111publ383.pdf. The definition from the Act refers to "materials critical to national security," which the team calls "strategic materials." Despite the title of the Act, the definition as provided in the Act is limited only to military materials. The team expands the scope of the definition to include all national security materials by the parenthetical insertions into the quoted text. The team's definition of "strategic material" includes the two key characteristics that a material be necessary to serve a national security requirement and that it be subject to a supply disruption. Other definitions of "strategic materials" and "critical materials" have currency, but they either do not contain both of these key characteristics or they expand the scope to matters beyond national security, such as economic or energy initiatives, cf, *DOE Critical Materials Strategy* (full citation below). See also endnote 1 in the Appendix.
[3] See footnote 2.
4 United States Geological Survey (USGS), *2010 Materials Commodity Survey*, Washington DC: US Department of Interior, p. 193. and the 2001 version of the same report, also p. 193. The threshold for import reliance was set at 90 percent for this particular analysis. One could certainly argue that any import percentage greater than 50 percent indicates an import dependency. At the 50 percent threshold, the number of critical materials with import dependencies was 33 in 2000 and 38 in 2010.
5 Titanium Metals Corporation, *U.S. Securities and Exchange Commission Form 10-K, Part 1* "Business". (March 1, 2010): p. 2. http://yahoo.brand.edgar-online.com/DisplayFiling.aspx?dcn=0001011657-10-000004, (accessed March 27, 2011).
6 Defense Logistics Agency, *DLA Strategic Materials Presentation*, Defense Logistics Agency: Ft Belvoir, VA, January 2011, slide 26.
[7] National Research Council, *Minerals, Critical Minerals, and the US Economy*, Washington DC, National Academies Press, p. 109-167.
[8] U.S. Department of Energy, *Critical Materials Strategy*, Washington, DC: U.S. Department of Energy, December 2010, p. 96-97.
9 Cindy Hurst, *China's Rare Earth Elements Industry: What can the West Learn?* (Washington, DC: Institute for the Analysis of Global Security,2010, p. 4-5
10 USGS,, *op cit, p. 16*
11 Roderick G. Eggert, "Access to Critical Raw Materials: A US Perspective," Public Hearing on Effective Raw Materials Strategy for Europe. European Parliament, Brussells: Committee on Industry, Research and Energy, January 26, 2011.p. 2
12 Ibid, p. 8.
13 Ibid., p. 8.
14 PDAC Molycorp Sees XSORBX Taking all of its Cerium Output," Metal Pages, http://www.metal-pages.com/news/story_print.php?id=52796 (accessed March 11, 2011).
15 United States Code, Title 30, Chapter 28, Government Printing Office. February 1, 2010. http://frwebgate.access.gpo.gov/cgi-

bin/usc.cgi?ACTION=BROWSE&TITLE=30USCC28&PDFS=YES (accessed March 27th, 2011).
16 Ibid.
17 U.S. Department of Energy, p. 59.
18.General Mining Act of 1872, passed May 10, 1872, 42nd Congress, Session II, Chapter 149 and 152.
19 Ibid.
20 GAO Report, Hardrock Mining, Information on Abandoned Mines and Value and Coverage of Financial Assurances on BLM Land (GAO Report), March 12, 2008, p. 1-5.
21 Ibid, p. 5..
22 Ibid., 8.
23 Ibid., 6.
24 National Mining Association Brief to the team, Mar 2011.
25 The Berry Amendment defined Specialty Metals as follows. Note that the criteria that define materials subject to the Amendment are fixed in time such that there is no discretion on what materials to which it applies, irrespective of the evolution of materials technology since the Amendment was written:

- Steel—
    - With a maximum alloy content exceeding one or more of the following limits: manganese, 1.65 percent; silicon, 0.60 percent; or copper, 0.60 percent; or
    - Containing more than 0.25 percent of any of the following elements: aluminum, chromium, cobalt, columbium, molybdenum, nickel, titanium, tungsten, or vanadium;
- Metal alloys consisting of nickel, iron-nickel, and cobalt base alloys containing a total of other alloying metals (except iron) in excess of 10 percent;
- Titanium and titanium alloys; or
- Zirconium and zirconium base alloys.

26 National Research Council,Committee on Assessing the Need for a Defense Stockpile. *Managing Materials for a Twenty-First Century Military.* National Research Council committee report, Washington, D.C.: The National Acadamies Press, (2008): 84.
27 Daniel H. Else, *Defense Production Act: Purpose and Scope*, *Report for Congress*, Washington, DC: Congressional Research Service, May 2009, p1.
28 James K. Jackson. "The Committee on Foreign Investment in the United States (CFIUS)" Congressional Research Service. (29 July 2010): 1, p. 2- 24.
29 National Research Council(NRC) *Managing Materials for a Twenty-first Century Military,* Washington, DC: National Research Council of the National Academiesop cit,, 2008, p. 83.
30 U.S. House of Representatives. "*Hearing regarding Reauthorization of the Defense Production Act of 1950*." Subcommittee on Domestic Monetary Policy, Technology, and Economic Growth and the Committee on Financial Services, First Session Serial No. 107-24 (13 June 2001): 5.
31 John Tkacik, Jr, , "Magnequench: CFIUS and China's Thirst for U.S. Defense Technology," The Heritage Foundation, http://www.heritage.org/research/reports/2008/05/magnequench-cfius-and-chinas-thirst-for-us-defense-technology, 6 Mar 2011.

32 Congressional Budget Office, *Strategic and Critical Nonfuel Minerals: Problems and Policy Alternatives,* Washington, DC: The Congressional Budget Office, 1983, p 64.
33 NRC, op cit, p. 2.
34 Ibid, p.127.
35 Defense Logistics Agency, *Strategic Materials Security Program (SMSP) Implementation Plan*, Ft. Belvoir, VA: Defense Logistics Agency, August 2010, p 2.
[36] A government source who provided inputs on a non-attribution basis. Defense Logistics Agency, "Strategic Materials Security Program (SMSP) Implementation Plan Report to Congress", August 2010.
[37] FY 2007 (John Warner) Defense Authorization Act, signed by the President Oct. 16, 2006. and the FY 2011 (Ike Skelton) National Defense Authorization Act, signed by the President January 7, 2011.
[38] Defense Logistics Agency, op cit, p. 10.
39 "Tariffs," METI, http://www.meti.go.jp/english/report/downloadfiles/gCT0004e.pdf, 6 Mar 2011.
40 NRC, op cit p. 82.
41 Trade Agreements," Office of the Unites States Trade Representative," http://www.ustr.gov/trade-agreements, 3 Mar 2011.
42 US Government Accountability Office, *Federal Procurement: International Agreements Result in Waivers of Some US Domestic Source Restrictions,*(Washington D.C. US Government Accountability Office January, 2005), 5.
43 Office of the U.S. Trade Representative (USTR), Comments for the team on April 12, 2011 at the Industrial College of the Armed Forces.
44 " Mugging Magnesium; How an antidumping case has destroyed U.S. manufacturing jobs," Wall Street Journal, http://online.wsj.com/article/SB10001424052748703296604576005782214829222.html 3 Mar 2011.
http://proquest.umi.com/pqdweb?did=2227543671&Fmt=3&clientId=3921&RQT=309&VName=PQD&cfc=1, 3 Mar 2011.
45 J. Korinek, J. and J. Kim (2010), "Export Restrictions on Strategic Raw Materials and Their Impact on Trade", OECD, http://www.oecd-ilibrary.org/docserver/download/fulltext/5kmh8pk441g8.pdf?expires=1299092748&id=0000&accname=guest&checksum=DA6612CB0A2906E7DD5526399E12C6B5. 2 Mar 2011.
46 Ibid.
47 Ibid.
48 "ITAR Self-Enforcement: How Much Do We Tell the Government?" Export Rules, http://www.exportrules.com/, 6 Mar 2011.
49 Ryan J. Zelnio, ., "Determining the Effects of ITAR Regulation on the Commercial Space Manufacturing Sector," *Consortium For Science, Policy & Outcomes*, http://www.cspo.org/igscdocs/Ryan%20Zelnio.pdf
50 Conclusions from a variety of industry sources who provided their inputs on a non-attribution basis.
51 White House, *National Security Strategy*, May 2010. http://www.whitehouse.gov/sites/default/files/rss_viewer/national_security_strategy.pdf (page 14)

52 Executive Office of the President chartered the Sub-Committee on Critical and Strategic Mineral Supply Chains, December 2010. http://www.whitehouse.gov/administration/eop/ostp/nstc/committees/cenrs. The use of the word "critical" is not intended to be applied to this paper—rather, it is the original title of the subcommittee, which we retained.

53 Executive Order (EO) 11858 establishing CFIUS can be found at http://www.archives.gov/federal-register/codification/executive-order/11858.html

54 The insight that departmental and agency parochialisms in the bureaucracy contributed to poor interaction at the interagency level under the existing statutory regimes was provided by a federal official to the team in a private conversation in May 2011.

55 Eggert, *Critical Minerals and Emerging Energy Technologies*, 1-59,, p. 1. Dr. Eggert notes examples of elements recently subjected to such large increases in demand include gallium, indium, and tellurium in photovoltaic solar cells, lithium in automotive batteries; and rare earth elements in permanent magnets for wind turbines and hybrid vehicles." See also Committee on Industry, Research and Energy, European Parliment, *Access to Critical Raw Materials: A U.S. Perspective*, 2011, .

56 National Research Council, *Minerals, Critical Minerals, and the US Economy*, Committee on Earth Resources, Washinton, D.C.: The National Acadamies Press, 2008. http://dels.nas.edu/resources/static-assets/materials-based-on-reports/reports-in-brief/critical_minerals_final.pdfp. 71-108.

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58 Dudley J. Kingsnorth, *Meeting the Challenges of Rare Earths Supply in the Next Decade*: Industrial Minerals Company of Australia Pty Ltd, 2010, Slide 25. AND Anonymous. "Prices report for Mr Michael Brown." Metal Pages. http://www.metal-pages.com/ (accessed March 31, 2011). Page 1 of 1

59 William Ascher and William H. Overholt, *Strategic Planning and Forecasting: Political Risk and Economic Opportunity*, New York: John Wiley and Sons, 1983, p. 22-34.

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61 Dwight D. Eisenhower to Charles Erwin Wilson, January 5, 1955, *In The Papers of Dwight David Eisenhower*, ed. L. Galambos and D. van Ee, doc. 1233, http://www.eisenhowermemorial.org/presidential-papers/first-term/documents/1233.cfm, accessed May 17, 2011.

62 Dwight D. Eisenhower, "Farewell Address" (Nationally televised presidential address, January 17, 1961), http://www.ourdocuments.gov/doc.php?flash=true&doc=90&page=transcript, accessed May 19, 2011.

63 Department of Defense. "Report of Meeting Department of Defense Strategic Materials Protection Board Held on December 12, 2008." Defense Strategic Materials Protection Board, 2008, 2-,9. To harmonize the work, the SMPB Executive Secretary established definitions for the following terms subject to final approval by the SMPB.

- Strategic Material – A material 1) which is essential for important defense systems, 2) which is unique in the function it performs, and 3) for which there are no viable alternatives.

- Material Critical to National Security ("Critical Material") – A strategic material for which 1) the Department of Defense dominates the market for the material, 2) the Department's full and active involvement and support are necessary to sustain and shape the strategic direction of the market, and 3) there is significant and unacceptable risk of supply disruption due to vulnerable U.S. or qualified non-U.S. suppliers

64 National Research Council of the National Academies, *Minerals, Critical Minerals, and the U.S. Economy*. Review of Summary. To further explain, the vertical axis allows identifying the importance of minerals in use and the horizontal axis allows one to assess the availability and reliability of a mineral's supply. Applying the established criteria, Be resides in the upper right quadrant meaning that it is very important to national security with no known substitutes, its use is dominated by Defense, and that its availability and reliability of supply could be at risk. *Scitech Book News*, December 1, 2008, 3-4 http://www.proquest.com.ezproxy6.ndu.edu/ (accessed March 20, 2011).

65 Materion. "Alloy Products." Materion. http://www.brushwellman.com/history.aspx?id=238. (Accessed 26 March 2011)

66 Department of Defense, op cit,p. 8.

67 Undisclosed Industry Informant.

68 "Spitzer Space Telescope." Aerospaceguide.net. http://www.aerospaceguide.net/telescope/spitzer.html The Spitzer Space Telescope launched in 2003, had its optics built of Be metal. Similarly, the James Webb Space Telescope will have 18 hexagonal Be sections for its mirrors. Because JWST will face a temperature of 33 K, the mirror is made of Be, capable of handling extreme cold better than glass. Be contracts and deforms less than glass due to its heat and cryogenic or cold change tolerance—remains more uniform in such temperatures encountered in space.

69 National Aeronautic and Space Administration,"The James Webb Space Telescope." National Aeronautic and Space Administration: `http://www.jwst.nasa.gov/mirrors.html`. Kelly Yamanouchi, "Time for reflection Boulder's Ball Aerospace & Technologies is finishing its work on a." Denver Post, 19 May 2005: 3.

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71 Air Force Space Command, Public Affairs Office. "Defense Support Program Satellites." U.S. Air Force. http://www.af.mil/information/factsheets/factsheet.asp?id=96.

72Undisclosed Industry and Government Informant– Mothballing the facility entails preserving the production facility without using it to produce. The machinery, plumbing, valves, etc. in the mothballed facility were kept in working order so that production could have been restored quickly if needed.

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74 Ibid, p. 171. http://www.nap.edu/openbook.php?record_id=12028&page=171.
75 Undisclosed Industry and Government Informant.
76 Undisclosed Industry Informant.

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