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Industry Study**

Final Report
Strategic Materials Industry Study



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Strategic Materials

ABSTRACT: Strategic materials encompasses not only the materials essential for a healthy economy and robust national security, but also mining, processing and related technologies, as well as the domestic and international politics and trade policies which affect access to traditional and emerging materials. For the United States to ensure its security, maintain its military force dominance, and enhance global economic competitiveness, it must address the lack of a coordinated materials policy. At a minimum, a coordinated policy must address trade, taxes, education, the environment, research and development, and production capacity within the industrial base. While providing recommendations in each of these areas there are specific recommendations for the creation of an interagency policy coordination committee and a critical minerals partnership comprised of government and industry representatives. The goal is to bring together all stakeholders and provide a forum for discussion that will lead to enhanced policy recommendations.

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 Army Research Development and Engineering Center, Picatinny Arsenal, Picatinny, NJ
 Kennametal Incorporated, Latrobe, PA
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 Metal Fabricators of Zambia Ltd (ZAMEFA), Luanshya, Zambia
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 First Quantum Minerals, Lusaka, Zambia
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 Department of Commerce
 National Mining Association

What We Did

The Strategic Materials Industry Study focused on gaining a complete understanding of the issues, impacts and concerns surrounding critical minerals essential to both United States (U.S.) defense needs and the national economy. The study began by analyzing the findings and recommendations of two recent National Research Council (NRC) reports, *Managing Materials for a 21st-Century Military* and *Minerals, Critical Minerals and the US Economy*. The study broadened its knowledge and understanding of critical minerals by interacting with a host of government, industry and academic minerals administrators, managers, producers and scientists, through a series of domestic and international field visits. Through these interactions the study confirmed the concerns raised in the reports; specifically, the absence of a coordinated materials policy and insufficient federal investment in critical minerals were recurring themes on our travels and in discussions with subject matter experts.

The seminar's domestic field studies centered on American manufacturers of finished and partially finished metal products. These interactions allowed the seminar to witness firsthand the production of titanium sheet, beryllium/copper pipe, tungsten carbide cutting tools, and titanium ingots. Many of these components are used in making defense products and systems. The group also visited both government and private research and development sites working on advanced metals processing. The seminar's visit to a local titanium sands mine set the stage for its international field studies in Zambia, Africa, to explore copper and cobalt mining and processing operations. Zambia plays an important role in the beginning of the value chain as a major world source of copper and cobalt. The explosive growth in global demand for minerals with concomitant significant price increases provides Zambia with an opportunity to take advantage of windfall profits to better the life of the Zambian people. These experiences enabled the seminar to understand and identify important issues including: emerging defense related minerals needs, domestic availability risks, and globalization's continuing impact on worldwide critical minerals supply, price and demand.

Integrating all of the knowledge gained, the study has built a comprehensive base from which to analyze and enhance current U.S. government policy regarding critical minerals. To support the recommendations developed by the seminar, this paper will first examine strategic materials as an industry and establish definitions for strategic and critical minerals/metals. This is followed by a review of current U.S. policies, market conditions and outlook for the future. After addressing the challenges that surfaced in our study, we provide our findings and recommendations. The policy recommendations acknowledge current weaknesses and provide a framework for enhancing national security and preventing disruptions to the nation's economy.

Strategic Materials – The Industry

Strategic materials is not an industry in the traditional sense that encompasses the manufacture of a specific product such as aircraft or automobiles. Strategic materials are a conglomerate of materials and manufacturing processes linked together to produce products as simple as copper wire and as complex as actuators for control surfaces of the F-22 aircraft. Almost everything we use in our technologically driven world from cell phones to automobiles contains minerals. The study of strategic materials includes every aspect of the material from the mineral's source in the earth's crust to the final application in an aircraft engine or satellite. The broad array of activities that impact the material's availability and price include mining, beneficiation, processing and manufacturing. The myriad of ways that materials impact our

personal lives, national defense, and the economy as a whole provide the backdrop for studying strategic materials.

The U.S. is 100% import dependent for 18 minerals and over 90% import dependent for four additional minerals. Very few minerals and materials are extracted from domestic sources. From a materials standpoint, we are dependent upon the world for the raw materials needed for critical defense items and production of everyday items. Interruption of the supply of these items will negatively impact national economic stability and defense needs. To understand how supply of critical minerals may be affected, it is vital to understand the entire material flow from the earth's crust to the finished product.

The classroom studies began with an analysis of two recently published reports that tackle the issue of mineral availability and their impact on the Department of Defense (DoD) and the national economy. *Managing Materials for a 21st-Century Military*, published by the NRC focused on the DoD's use of the National Defense Stockpile (NDS) and its relevance in today's strategic environment. *Minerals, Critical Minerals and the U.S. Economy* (hereafter referred to as the MCM report) published by the NRC addressed non-fuel minerals in the larger context of their impact on the U.S. economy. The report proposed a criticality matrix as a tool for addressing risk in access and impact of supply availability for individual minerals. These two documents helped shape our study of strategic materials by providing the framework to evaluate materials impact on the DoD and in the larger strategic context of the nation's economy.

The seminar visited several mining and smelting operations in the U.S. and in Zambia to understand the challenges facing the first stages of obtaining minerals and transforming them into usable metals. The next step after extraction includes turning the powder, ingots, and slabs into mill products sold to manufacturers and through them, products to end users. Every stage associated with the extraction and use of minerals presented challenges at the local, federal and global levels. The problems ranged from environmental compliance and human capital, to energy access and global competition.

Before further exploration of minerals and the challenges associated with obtaining and processing them into end products, we must examine the terminology used to describe minerals and materials.

Definitions

The definitions of "strategic" and "critical" require consideration before an integrated U.S. policy on minerals can be developed. We encountered differing uses of the terms as we engaged in discussions with representatives from various government agencies. The (MCM) report defined strategic mineral/material as items that are needed during time of war, national emergency, or for military use that are not found or produced in the U.S. in sufficient quantities to meet needs. The report defines a critical mineral as one that performs an essential function for which there are few or no satisfactory substitutes.¹ The definition of the term "critical" provided in the MCM report is broader than the definition of "strategic" employed by the DoD. The MCM report considers all aspects of the U.S. economy and does not limit the evaluation to defense needs.

The MCM report suggests the defense-based definition of strategic is of limited use when examining supply risks and substitutability to develop policy because criticality also encompasses economic and social functionality if essential products cannot be provided.² The Strategic Materials Protection Board, an entity created by congress that reports to the Secretary of Defense, is tasked with determining the need to provide a long term domestic supply of

materials designated as critical to national security to ensure that national defense needs are met. The board analyzes the risk associated with each material designated as critical to national security and the national defense impact of the non-availability of a material from a domestic source. The board has identified only two materials, beryllium and industrial quartz crystals, as critical.³ The MCM report evaluates three minerals or families of minerals that met their criteria for critical and proposed eight additional minerals that could potentially become critical. All of the minerals reviewed in the report have the potential to disrupt economic activity and have few viable substitutes.

The differing definitions of critical across the U.S. government are evident when examining the Department of Commerce's (DoC) stance on critical materials. The definition of critical materials used by the DoC is more akin to the approach proposed in the MCM report, but goes further, defining every material affecting the U.S. economy as a potentially critical material. Regardless of which items are declared strategic or critical, the definition of a "strategic mineral/material" is clearly tied to defense needs and availability for defense purposes while the term "critical mineral/material" focuses on the larger national economic impact of availability and substitutability.

The criticality matrix, Figure 1, provided by the MCM report provides a solid framework for evaluation of a mineral. The matrix provides a national economic impact perspective on minerals as opposed to a defense centric view. From a DoD perspective, the criticality matrix is useful for many purposes. For example, in developing acquisition programs, DoD can use the matrix to better understand the impact of substitutability constraints and/or supply disruptions on materials intensive programs. With this knowledge, the department can better structure programs to avoid related risks, ensuring that systems reach the war fighter on time, within budget and meet performance expectations. From a national economic perspective the matrix is an analytical tool that identifies areas of risk that have strategic implications. By identifying the risks, trade and other policies can be shaped based on the application of the matrix.

From a strategic policy perspective the matrix addresses many types of availability: geological, technical, regulatory, environmental, social, political, and economic. None of these factors alone can provide enough information, but when taken together create a broad picture of the situation surrounding a mineral or material's supply risk and the impact of supply restrictions.

For the period 2003- 2006, China supplied 84% of the REEs consumed in the U.S. along with France (6%), Japan (4%), Russia (2%) and others (4%).⁴ The large import dependence on one nation along with growing internal demand from China creates a serious potential for future supply disruption. The import figures do not reflect the fact that although there are other sources of REEs, China accounted for 97.6% of global mine production in 2006. Twenty one percent of the world's REE reserves are in the U.S. and Australia, nations without REE production. An additional 25% of the reserves are in nations that account for only 0.3% of global mine production.⁵ While there is some substitutability with rare earths, the impact is reduced performance. The REEs encompass all aspects of a critical mineral, low substitutability and high risk for supply interruption, coupled with domestic sources that are currently unavailable due to environmental constraints.

By plotting the impact of supply restriction (substitutability) on the vertical axis and the supply risk on the horizontal axis, four quadrants emerge ranging from low impact/low supply risk to high impact/high supply risk. Using the matrix, a mineral with low substitutability but with assured sources of supply poses low risk. However, a mineral with an insecure source or

the potential for disruption of supply could pose significant risk to industry and the economy. For example the matrix evaluates the Rare Earth Elements (REE) as high impact due to low substitutability and high supply risk based on 100% import dependence for these minerals. Uses for REEs include automotive catalytic converters, metallurgical alloys, petroleum refining catalysts, cell phones, and high energy magnets. This dependence on foreign suppliers will soon end. The only U.S. source for REEs is a mine owned by Molycorp in Mountain Pass, California, that closed for environmental reasons in 2002. However, Molycorp has all permits in place, including a 30 year mining permit, and expects to resume mining in 2010 with full operations by 2012.⁶ Molycorp anticipates strong sales based on strong demand from rare earth magnet manufacturers.⁷

When using the matrix, one must remember that criticality is dynamic. Factors that impact substitutability, such as technological advances and cost, change over time. Additionally, political and trade conditions vary as nations adjust taxes, tariffs, and other policies that impact availability and ease of export. In the case of REE, the reactivation of a domestic producer promises to change the current supply risk assessment dramatically.

Globalization is a key factor that impacts the dynamic nature of the criticality matrix. The focus on import dependence as it relates to supply risks masks the impact of rising demand in emerging economies and the resultant increase in competition for scarce resources. China's emergent economy, rapid urbanization, and restrictive trade policies have stressed the markets for many mineral commodities, lowering supply and increasing costs. China has reduced export quotas and imposed export duties on REEs, fluorspar, and tungsten. China is not the only concern. Dumping of low cost material by Russia is also an issue in the vanadium industry. Russian companies were recently asked to divest of their holdings in South Africa by the European Commission due to concerns over their ability to monopolize the vanadium market.⁸ Later in the paper we will review China's record against the backdrop of globalization.

The factors of criticality mentioned earlier including geological availability, technical availability, regulatory availability, environmental and social availability, political availability and economic availability are heavily influenced by globalization. Issues such as availability of electricity for mining, beneficiation, and processing were raised on many of our field studies in the U.S. and Zambia. Social issues include the lack of trained personnel and exploitation of resource rich nations by foreign companies. From an environmental perspective the challenge is achieving balance between reliance on import sources versus acceptance of the environmental impact of mining. Rising minerals prices may make previously uneconomic deposits viable business opportunities.

From the foregoing discussion it is clear that what are strategic or critical changes over time. The definition varies across different segments of the federal government. The DoD perspective is too narrow and does not account for items that are vital to the nation's economic engine. The DoC definition is too broad and includes all items without sufficient limitations. The U.S. economy is a vital national interest, and any disruption in the supply of a material critical to the effective functioning of the economy is a risk that the nation must proactively address. Any severe disruption of the economy will adversely impact national security.

The impact of globalization is of great importance given the risk to supply and the likelihood of increased demand pressures for materials in emerging economies. The definition of critical established by the MCM report along with the criticality matrix provide the foundation for further exploration of issues associated with critical minerals and U.S. policy. In addition to an understanding of critical minerals and metals, it is also important to have a firm grasp of the

U.S. policies and tools which currently impact them.

Metals, Materials, Manufacturing and U.S. Policy

Current policies pertaining to Defense acquisition of minerals include the Defense Production Act (DPA), the National Defense Stockpile (NDS) legislation, the Buy American Act, the Berry Amendment, and the Specialty Metals provisions. Taken in isolation, each policy has a positive influence on a particular domestic industry or product. However, lack of cohesion amongst these policies often has an adverse impact on the acquisition and support of systems necessary to ensure national security. This approach also results in manufacturers delivering defense systems and capabilities later than required and at higher costs than if the U.S. left sourcing considerations to the global marketplace. We will explore each of the policies in turn.

The Defense Production Act (DPA)

Congress enacted the DPA in 1950 to expand production and ensure economic stability during the Korean War. The current DPA legislation expires September 30, 2008; the Federal Emergency Management Agency (FEMA) is coordinating its reauthorization. An overview of the current titles follows.

Title I grants the President substantial latitude to mandate that U.S. industry provide defense, energy and emergency preparedness goods at a higher priority than commercial goods. Title I utilizes a rating system for defense orders with a rating of “DX” for those programs designated as having the highest national urgency, “DO” for other programs, and no rating for those not designated as DX or DO. Hierarchical in nature, DX rated orders take priority over DO rated orders, which appropriately take priority over unrated orders. Currently, DoD has authorized the assignment of DX to only nine defense programs.⁹

Title III authorizes the President to expand and protect the U.S. industrial base to meet government security requirements. In effect, Title III empowers government to change the domestic industrial base and provide incentives to ensure viable productive capacities exist. DoD rigorously reviews all projects for a Presidential determination. It is important to note that no DPA provision exists to support a program merely for economic reasons, meaning that DoD will not initiate a Title III program to find a less expensive source of materials (nor should it). Currently there are over 30 ongoing Title III projects.

Finally, Title VII protects firms from claims for non-performance on unrated government contracts when the non-performance was directly attributable to complying with the requirements on rated orders. Title VII authorizes the suspension or prohibition of the acquisition, merger, or takeover of a domestic firm by a foreign firm if that action threatens national security. The U.S. Committee on Foreign Investment administers this provision.

The National Defense Stockpile (NDS)

Congress established the NDS in 1939 to serve the interest of national defense and not for economic and budgetary purposes.¹⁰ At its peak, the NDS had about 93 minerals in quantities to satisfy an estimated three-year demand. Today the strategic stockpile contains less than 20 items with all but two set to be sold. When the Cold War ended in the 1990s, Congress directed sales from the stockpile as a means to achieve a “peace dividend” and generate revenue.¹¹ At present, there is a worldwide shortage of many of these critical minerals, most of which are no longer in

the NDS, and most are ones where the U.S. is highly dependent on a limited number of potentially unstable sources of supply, which results in increased prices for all the items in demand.¹²

The changing nature of the worldwide marketplace via globalization and “free access” to critical minerals makes the U.S. economy more vulnerable to supply chain disruptions due to events beyond our shores. For example, a 1949 Russian embargo of manganese and chromium, critical for the manufacture of specialty steel, was imposed as a political response.¹³ In 1969, a months-long strike at a Canadian nickel company sent nickel prices soaring and users scrambling for supplies.¹⁴ From 1974-1979, molybdenum was in short supply around the world because of reduced copper production (molybdenum is a by-product of copper mining), a U.S. mine was not yet operational, and a nine month strike at a Canadian mine caused a three-fold jump in market price.¹⁵ And in 1978-1979, a “cobalt panic” was ignited by a combination of increased world demand that created a buying frenzy, even though production by the two largest producers increased in both years.¹⁶

The world today is too unpredictable to take the risk that our supply chain will not be interrupted by incidents thousands of miles away. From a strategic perspective, the interruption in the supply of critical minerals is an increasing vulnerability that must be assessed and potentially mitigated by the U.S. government. Potential risks to the U.S. economy dictate that a consolidated national materials management policy must be developed, which is contrary to many current government agency views. To further complicate this issue, several agencies with interests in minerals each have separate and divergent policies. There is simply no unified overarching national materials policy to assure continued production of vital military and commercial goods – and one is needed to establish a consistent and unified national approach.

Buy American Act, Berry Amendment and Specialty Metals

Signed in 1933, the Buy American Act mandates that government agencies procure items produced with at least 50% of U.S. materials and labor. Congress later passed the Berry Amendment,¹⁷ which restricted the military services to purchase products produced with 100% U.S. materials and labor. Originally intended to ensure that only U.S. products and services clothed and fed American troops, the law has continued to evolve through the years. Since 1941, every Authorization Act has contained Berry Amendment adjustments, such as the inclusion of the specialty metals terms of reference.

Specialty metals, which include certain steel, titanium, zirconium and other alloys, became part of the Berry Amendment in 1973 following congressional testimony by Vice Admiral Eli Reich.¹⁸ He asserted that subsidized imports damaged the specialty metals sector and recommended the government intervene to guarantee that the U.S. would retain a specialty metals industrial base. The Berry Amendment requires DoD to procure all specialty metals for defense needs from either U.S. sources or qualifying countries unless a defense contractor is able to qualify for one of the narrow exceptions to the law.

DoD policy makers have continuously struggled to find the best way to manage the specialty metals arena. When Congress first incorporated specialty metals into the Berry Amendment, then Secretary of Defense Melvin Laird declared it would be too difficult to enforce compliance throughout the entire supply chain. Accordingly, DoD focused compliance efforts on the first two tiers in the supply chain.¹⁹ Reacting to Congressional pressure in 2005, and after discovering numerous Berry Amendment infractions, DoD began requiring one hundred percent compliance throughout the supply chain. This drastic policy shift created

significant problems for prime contractors because the sourcing of specialty metals in today's global market makes it nearly impossible to identify the source of every component of every product throughout the chain. The Berry Amendment Reform Coalition lobbied Congress to lift some of the restrictions from the amendment while still considering national security issues. Congress changed the law in 2007 and 2008 to clarify and correct problems that the previous legislation created.

Confusion often arises between the Buy American Act and the Berry Amendment / Specialty Metals provisions. The Specialty Metals clause²⁰ is in addition to the Buy American Act for DoD procurements, so a contractor may be compliant with Buy American, but be in violation of the Specialty Metals law. The Buy American Act requires that only 50% of the source material come from domestic sources, and when the U.S. has a Free Trade Agreement with a specific nation, the 50% restriction disappears. However, under the Berry Amendment and the Specialty Metals provision, all products must be 100% domestically produced which can lead to production delays and cost over-runs. There is an exception to the Berry Amendment and Specialty Metals provision for national security waivers, but the authority lies with the Secretary.

Now that we have a solid background on current legislation from which to draw, we are ready to discuss the current market conditions pertaining to critical minerals and materials.

Current Market Conditions

There are several challenges inherent in ensuring that U.S. processors and manufacturers have a secure supply of critical minerals and materials necessary to the functioning of the U.S. economy, and thereby meet national defense acquisition requirements. This section analyzes the recent past and current condition of non-fuel critical minerals through the lens of beryllium, cobalt, titanium, and tungsten metals sectors. The seminar reviewed these sectors in great detail and identified the significant issues affecting the supply of these critical materials so necessary to the U.S. economy. An essay later in the report will further explore titanium, beryllium and REEs.

The critical minerals/metals market is highly cyclical with significant booms and busts, largely in line with world economic fortunes. As recently as 2000, several metals processors were losing money, titanium processors being a prime example. The nation's sole beryllium processor closed its primary production facility in 2000. This resulted in government intervention to assure future production capacity of this strategic metal.²¹ In addition, the only domestic REE mining operation closed in 2002, largely due to domestic environmental issues.²² However, current conditions reflect record demand for critical metals and the minerals from which they are made. Increased demand for critical minerals has been fuelled by China's rapid urbanization and economic growth (along with India's). Innovation and improved technology have resulted in new applications for critical minerals/metals, which of course have further driven demand. In turn, high demand has led to high prices, and even though metals processors are running at or near full capacity. Manufacturers further down the value chain often experience longer supply lead times. Price increases have been dramatic. For example, the United States Geological Survey reports titanium prices are up 400% over the past five years, while beryllium is up 150%, and cobalt is up 372%. In terms of delivery delays the current lead times for titanium orders have surpassed one year in many cases.

While high demand means higher prices for end-products, and delays in production schedules, there have been positive outcomes. Our visits to U.S. minerals processors illustrated their drive to meet demand and lower production costs through process improvement, research

and development, and increased plant capacity. Some operations which were previously uneconomical are now viable based on current high prices and are now back in operation. In the case of titanium and tungsten, U.S. processors are actively pursuing expansion in their melting, milling and fabrication capacity. We witnessed the same phenomenon in our travels to the copper belt in Zambia – private enterprise is driven to ensure higher profits and market-share by expanding capacity and reducing costs of production. In other words, market forces are at work to solve demand requirements.

While globalization has provided access to new ore and metal suppliers, the increase in supply is still being outstripped by demand. As dependence on foreign sources increases, it becomes more difficult to track the source of initial supply. In turn, this leads to difficulty in assessing whether the source of minerals and metals critical to the U.S. economy is assured and/or whether there is a risk of supply failure.

One effect of the current conditions regarding the relative scarcity of some metals and projected price increases is an increase in long term agreements at each step in the supply chain to secure access at lower prices. In the case of titanium, major commercial aircraft manufacturers have signed multi-year contracts with titanium providers to procure defined annual quantities of the metal. These producers, in turn, have similar long term agreements with titanium sponge suppliers to ensure their capacity.

In terms of research and development (R&D) funding, government, industry, and private organizations have split the R&D investment between developing new material alternatives and finding cheaper ways to produce some existing materials. This split is largely a function of the maturity of the specific industry, with established industries tending to focus on ways to reduce costs. However, some of these mature industries, such as titanium, have not aggressively pursued low cost production through alternate technology. Thus, DoD has made a significant investment over the past five years to develop a low cost titanium production process which would allow for products to be manufactured directly from titanium powder, without the need for production of titanium sponge and melting into metal.²³ We encountered strong advocates for investment in titanium powder metallurgy which could greatly reduce production costs and result in cost savings to DoD procurement. However, a significant breakthrough in the powder process is yet to be made.

While the U.S. economy has not been drastically impacted by inability to secure stable supplies of critical minerals and materials, many U.S. manufacturers have suffered time lags in delivery. Globalization has increased the number of major role players seeking strategic materials, which has resulted in the majority of minerals coming from foreign sources. As noted previously, import dependency is not a problem provided the source is assured and there is no risk of supply disruption. But problems can and do arise. Many critical minerals are supplied by China, and it is worthwhile to review China's record against the backdrop of globalization.²⁴ We will examine China's role in the global critical minerals/metals marketplace, beginning with REEs.

China and REEs

According to the DoC, China supplies nearly all of the world's REEs which are so vital to manufacturing and petroleum processing industries (not to mention their importance in defense applications). In 2006, 91.8% of U.S. imports of REEs came from China (a total of 26,000 tons). Unfortunately, China has set declining export quotas (only 46,000 tons in 2008). Even without considering increased U.S. consumption of REEs, that leaves the rest of the world

with only 20,000 tons. To make matters worse, the Chinese have imposed a 10-15% export duty on REEs, providing an impetus to keep the REEs in China.²⁵ If the cost for REEs within China were to be kept artificially low, while costs to foreign markets remain high, it would constitute an unfair trade practice on China's part.

The U.S. dependence on imports from China comes at a time when REEs have become increasingly important in defense applications, including jet fighter engines and other aircraft components, missile guidance systems, electronic countermeasures, underwater mine detection, antimissile defense, range finding, and space-based satellite power and communication systems.²⁶

China and Fluorspar

Again, according to the DoC, 65% of U.S. fluorspar imports²⁷ come from China. China has imposed export quotas, which declined dramatically from 710,000 tons in 2006 to a projected 500,000 tons in 2008.²⁸ As with other commodities China has imposed export duties on fluorspar to incentivize keeping it and processing it within China. As noted with REEs, the U.S. must remain vigilant regarding pricing concerns and unfair trade practices.

China and Tungsten

The DoC noted that China accounts for 85% of world production and 46% of U.S. imports. Again, China has imposed declining export quotas and export duties of 5-15% on ammonium paratungstate, tungsten oxide and powder, as well as a production tax of 7-9 Yuan per ton.²⁹ While Chinese production of tungsten has increased, export quotas have remained static. China is now issuing export licenses which make it more difficult to obtain the base metal and easier to get the finished product. Such a process means lower costs for tungsten within China and less tungsten available to the rest of the world, thereby driving prices up outside China, and constituting an unfair trade practice.

China and Titanium

According to the DoC and the USGS, the U.S. is projected to require more titanium to meet industry's needs in the near to long-term.³⁰ It is projected that the U.S. firms will increase titanium sponge capacity by nearly 100% to approximately 41,000 metric tons by 2012. During the same period, the Russians will increase their production to nearly the same amount. China is also projected to increase sponge capacity, but by more than 100% to approximately 95,000 metric tons by 2012.³¹ By 2012, total world production will have nearly doubled 2002 production rates. While some might argue that increased supply will mean lower prices, projected demand does not bear this out. With China projected to be the largest producer of titanium sponge, China will be able to exert inordinate pressure on the titanium market. Given China's record with export quotas and unfavorable pricing policies, one might expect the same behavior with titanium sponge.

Yet that is not where China's impact ends, since China is expanding holdings in Africa and elsewhere in the world to secure sources of critical materials for its burgeoning growth. Over the course of our studies we learned of China's mining exploits, which were highlighted in our visit to Zambia. While other producers have excellent safety records and sound labor/management relationships, Chinese mining operations were reported by local sources to be less safe and had a reputation for poor labor practices and poor community relations.

Nonetheless, China's interests in African minerals and other natural resources will lead to additional supply, but both the DoC and USGS anticipate that China's growing demand will outstrip supply, leaving no room for reductions in world prices for such commodities.

Turning now to U.S. domestic policies pertaining to mining, many issues complicate U.S. mining operations, such as the antiquated (1872) general mining law that has yet to be updated to account for new conditions.³² Most U.S. mineral reserves happen to be on federal land and a complex permitting system can often require years for a private company to obtain a license for exploration and mining operations. Outside of the U.S., start-up of a mining enterprise is often accomplished much more quickly. For example, in Zambia, there are several companies specifically dedicated to exploration for potential mineral deposits and future development and the permitting process can take as little as a few months.

Mining and manufacturing companies are also having difficulty recruiting mining workers, and this is a worldwide challenge. Fewer workers are entering the skilled machinery workforce and many potential college students are avoiding the geology field because of the historically cyclical nature of the industry.

Mining issues aside, U.S. metal manufacturers have approximately a 27% cost disadvantage than other nations due to energy, health care, wages and taxes.³³ The rising cost of energy alone is a huge disincentive to produce metals in the U.S. A good illustration of this is aluminum production which has dropped from 5 million tons to only 2.2 million tons per year over the past 20 years.³⁴ Clearly, U.S. policymakers must take into consideration the third and fourth order effects of policy decisions. The U.S. policies must be streamlined and well coordinated in order to best meet U.S. interests, though there is presently no governmental body chartered to accomplish this function.

The Zambian Case

The U.S. has long been a major consumer of materials and held a dominant position in the mining industry in the past, domestically extracting many of the minerals it consumed and being a major exporter to world markets. However, the U.S. has significantly shifted its position from a major minerals exporter to an importer of most of its minerals. As such, we are keenly interested in the stability of countries and regions that help sustain our materials base. Our visit to Zambia, a key country in the global supply chain for copper and cobalt, showed us that supplier countries also face many new challenges in deciding how to manage mineral resources. How countries similar to Zambia cope with these challenges are of key interest to the U.S. industrial base.

Exploding economic growth in China and India has meant an expansion in global demand for copper and cobalt. This has had dramatic effects on Zambia. While only 6% of its gross domestic product (GDP), copper and cobalt account for about 65% of Zambia's exports. The value of these exports has more than quadrupled since 2002.³⁵ The boom in minerals has brought Zambia large increases in foreign direct investment, as well as an important new patron – China. Yet Zambia's experience has proven that globalization is hard to optimize. Privatization of mining in the 1990's helped fuel the boom in the minerals industry, but expanding profits in the mid-2000's have reignited domestic concerns about foreign exploitation and provoked substantial increases in government taxation of the industry that could inhibit future growth without improving the benefits of the average Zambian.

Hopes for additional income from minerals rely on prices driven by fluctuating demand elsewhere. At the same time, minerals production in Zambia is highly vulnerable to both transient and persistent problems posed by its inadequate road and rail networks and electric power infrastructure. Amidst all this uncertainty, the government must find ways to finance and execute costly infrastructure improvements while balancing other urgent social and economic needs.

Resolution of the Zambian government's differences with the largely foreign owned mining companies will be closely linked to its credibility in honoring contractual agreements, its ability to deliver the needed electric power, and its investment in ground transportation networks. Political disputes over who should fund these investments, and how the industry might share costs, could disrupt exploration, production, and delivery of minerals and mineral products at any time.

Forecasting the outcomes of these economic and political dynamics will continue to be uncertain. Risks exist for all parties. Yet it is also clear that the judgments of decision makers in countries like Zambia become an important component of the dynamic global minerals marketplace – judgments that ultimately affect the availability and price of minerals for the U.S.

Market Projections

The short-term outlook for the worldwide critical minerals/metals market is very favorable because mineral prices have risen dramatically over the past five years primarily due to the increasing demand outlined above. For example, titanium has increased from just \$3.00 per pound in 2003 to over \$50.00 per pound in 2008, even though production costs remain stable.³⁶ As with titanium, short-term demand for REEs, tungsten, copper, cobalt, fluorspar, and others is expected to remain strong. Continued high demand and high prices in the short-term are likely to fuel increased exploration, processing and production capacity.

In the long-term, the continued growth of demand in China and India over the next 20 years will sustain the favorable outlook for the critical minerals and critical materials markets. That said, China's control of an overwhelming percentage of key strategic minerals must be mitigated. This and other issues impacting the supply of critical minerals and materials will be addressed in the Challenges section of our report.

Challenges

In the course of our travels and through information provided by guest lecturers several recurring themes or challenges emerged. For clarity, they are outlined briefly below.

1. **Globalization** — Supply and demand patterns are changing due to increased materials demand from emerging economies. Exporting nations face pressure to hold onto resources for internal consumption. High materials prices drive exploration and mining to areas with low barriers to extraction.
2. **Import Dependence** — As noted above, the U.S. is increasingly import-dependent for many critical minerals/metals. That said, this is not of itself a bad thing, provided sources are assured and supply disruption is not likely.
3. **Information Sharing (or lack thereof)** — Globalization makes it difficult to ascertain the initial source of many critical minerals/metals. The information that is

available within government departments is not adequately shared across the various agencies that have impact on effective management of and policy development for, critical minerals/metals.

4. **Energy** — Energy sources are vital to the extraction, refining, and forging processes, especially electricity and natural gas. The processes are energy intensive and contribute significantly to costs. Deregulation and increased demand for energy impact the ability to expand operations within the U.S. In our travels to Zambia it became very clear that an assured energy supply is critical – Zambia’s government will need to take steps to improve the electrical grid in order to facilitate growth in the mining and minerals processing sectors.
5. **Trade Policy and Tariffs** — Export restrictions impact the ability of U.S. firms to acquire needed items. The U.S. uses tariffs as a tool to protect domestic industry and prevent dumping of low cost material in the U.S. market. The DoC has been instrumental in ensuring that U.S. firms can compete in a fair and open market. The DoC will continue to be key in dealing with unfair trade practices such as those outlined above in the section on China.
6. **Taxes** — Taxes are tools that influence the behavior of business and must be evaluated before implementation to ensure desired outcomes are achieved.
7. **Human Capital** — Both overseas and domestically industry expressed concerns over a lack of trained engineers and scientists. Materials science education is sorely lacking in the U.S. For example, the number of Bachelor of Science degrees in metallurgy and materials science did not increase at all between 1967 and 2002.³⁷ There has also been a dramatic decline in the number of post-secondary institutions offering post-graduate degrees in mining and materials sciences. Clearly there is a need in the U.S. and elsewhere for more science, technology, engineering and mathematics graduates.
8. **Investment in Research and Development (R&D)** — R&D is a means by which to reduce waste, find more efficient recycling methods, and to replace scarce minerals with more readily available ones. R&D is key to maintaining a competitive edge in the global economy.
9. **Environmental Concerns and Land Use Agreements** — Both environmental concerns and land use agreements have mostly increased the cost of doing business for continued mining operations in the U.S. In years past, the extractive industries had caused significant environmental damage at a number of mining and processing sites with dangerous waste products entering the water and soil. The state and federal environmental laws were designed to prevent such abuses of the common lands. The difficulty for mining companies is not simply the cost to dispose of their waste products, but different permitting laws that are not coordinated and have conflicting requirements in some cases. During our visits to numerous mining and processing operations, we were favorably impressed by the extent of environmental awareness, chemical and material recycling, waste stream management, and land reclamation being practiced by the companies.

These challenges encapsulate the issues that impact policy decisions for the nation as a whole. We focused on these issues in shaping our findings and recommendations.

Findings

We found that the global supply of minerals and metals to the U.S. economy, and by extension to the DoD, is generally functioning properly – that is, markets are working. While it is true the U.S. relies more heavily on imported materials than in previous years, that dependence is not necessarily a problem. It only becomes a problem to the U.S. economy when those minerals and metals are required and suitable substitutes do not exist, or when there is a significant supply risk. Minerals which have a high impact in their respective industries combined with a high supply risk for any combination of geological, technical, social, environmental, political, or economic reasons are considered critical minerals. The Criticality Matrix methodology developed by the Committee on Critical Mineral Impacts on the U.S. Economy is a useful tool to categorize and illustrate which minerals are critical.³⁸ For most mineral access issues, the market mechanisms function adequately. Where market failures or foreign government actions adversely affect the availability of the minerals and metals required to support the economy, government intervention may be required. Whichever stance the government takes, an effective policy strategy must take into consideration the second and third order effects of policies to ensure that they are affordable, consistent, transparent and enforceable. It becomes imperative for government to intervene in cases where the strategic minerals are critical, such as with beryllium.

Globalization and international market forces dominate the extractive industries. The current demand for metals is a direct outcome of the growth in the world economy led by China, India, and other emerging economies. We observed supply in both the U.S. and Africa expanding rapidly to meet the high demand of the market.

Plentiful and inexpensive energy sources are vital to the extraction, refining, and forging processes, especially in the form of electricity and natural gas. The processes are energy intensive and contribute significantly to costs. Domestic deregulation and increased demand for energy impact the ability to expand operations in both the U.S. and Zambia. In the U.S. the constraint is primarily increased electric energy cost, while in Zambia electricity is in short supply even though the mining industry receives preferential access to electric power.

Human capital shortfalls in the form of educated and experienced scientists and engineers are an issue in both the U.S. and Zambia. The downsizing of the extractive industries in the U.S. in the 1990's has led to a shortage of trained and educated personnel in the 2000's. Many U.S. colleges eliminated their mining engineering programs based on reduced demand. In Zambia, the expansion of the mining industry has produced a demand for trained staff that cannot be filled internally. Hence, work permits are being issued to foreign expatriates to supply the required skills to Zambia's Copperbelt region.

We agree with the conclusion of the Committee on Assessing the Need for a Defense Stockpile that the "design, structure and operation of the National Defense Stockpile render it ineffective in responding to modern needs and threats."³⁹ While the stockpile could have a role as part of a more comprehensive DoD strategic materials management policy, that change would require a complete overhaul of guidance and operating authorities to a much more flexible, market oriented structure.

Policy Recommendations

We propose a number of policy recommendations for those situations where government has a role in reducing adverse impact or reducing supply risk. Because the global marketplace is dynamic, the circumstances around a critical mineral's availability and importance must be constantly monitored. Government intervention in the market is frequently disruptive and so it should be an objective of the government to allow market forces to operate to the maximum extent possible, consistent with national interest.

1. **Minerals Policy Coordination Committee (PCC)** — We propose an interagency Policy Coordination Committee, reporting to the National Economic Council that will oversee the myriad minerals policies across the government that impact critical and strategic materials. Under the leadership of the Departments of Commerce and Interior, the interagency PCC should include representation from Defense, State, Energy, Education, and the U.S. Trade Representative's office. The role of this PCC is to set and coordinate federal minerals policy across the government to ensure access to foreign sources of critical minerals and facilitate domestic extraction, as appropriate.
2. **Critical Minerals National Policy** — The PCC will establish a critical minerals national policy that provides the guidelines and criteria for government intervention and the metrics for success.
3. **Minerals Data** — We propose enlarging the mission and expanding the funding for the U.S. Geological Survey to further develop complete and comprehensive information on all minerals to inform both policy makers and the public. The expanded data should cover domestic and international reserves of minerals.
4. **Critical Minerals Partnership** — We propose establishing a collaborative government / industry partnership to meet the collective challenge for access to critical minerals used as industrial building blocks. The government and industry came together in the 1980's and re-established American competitiveness in semiconductor manufacturing technology.⁴⁰ Similarly this model will provide a coordinated effort to ensure that American industry has the critical minerals required to compete globally and to meet national defense requirements. We believe there is benefit to opening membership to companies from allied countries. The Critical Minerals Partnership would invest on a cost-sharing basis in R&D and work toward the following goals:
 - Accessible supplies of scarce or unreliably sourced elements
 - Beneficiation processes to make low grade ores economically viable
 - Less energy intense production processes
 - Cost-effective substitute materials
 - Efficient material recycling processes
 - Production processes with reduced environmental impacts

A few words on what the Partnership is not. It is not intended to usurp the power of the free market. Where the markets work, the Partnership would not be involved. It is not a government subsidy of the raw materials required by industry. The government's contribution would be towards research, development, and investment with broad benefit across industry in an area where markets have failed. It is not a means by which to level industry's competitive advantage. The Partnership's involvement would stop at the point where industry can obtain the critical minerals it requires to supply its value stream.

From that point forward, companies would be expected to compete in the global marketplace on their own merits. It is not a usurpation of the responsibilities of the United States Trade Representative (USTR). In fact, we expect the USTR to participate as a member of the interagency policy coordination committee.

5. **Education** — Research, development, innovation, and discovery cannot be sustained without technically competent personnel. There has been an attrition of competencies related to the finding, extracting, processing, and use of minerals and metals. The federal government does not deliver education directly but influences its direction by providing information to the public and incentives to guide choices. We recommend the federal government provide guidance to the states on opportunities for minerals and metals related occupational specialties, such as geology and mining and minerals process engineering. We also propose the U.S. government incentivize science and technology education through Science Technology Engineering and Mathematics (STEM) programs as well as scholarship programs at the federal level to encourage science studies.
6. **Energy Policy** — The availability of plentiful, inexpensive energy is key to the competitive beneficiation and refining of most minerals into useful metals. A national energy policy must include consideration of the energy required to process and refine minerals. The U.S. must decide as part of its national policy whether to make or buy its critical and strategic materials. If the nation does not allow for the energy to process and refine ores, then it will make the decision by default to importing the materials required to support industrial and defense activity. The larger question is: what degree of dependence does the U.S. want to have on foreign markets to provide its critical minerals and metals?
7. **Taxes, Tariffs, and Trade Policy** – We recommend the use of tax policy to encourage desirable behaviors in the private sector such as encouraging long term agreements for critical minerals and metals, and maintaining extra inventory to weather supply interruptions. We also recommend the use of tariffs and trade agreements as tools to ensure access to critical minerals and to mitigate political and economic supply risks. Recommendations concerning taxes, tariffs, and trade policies would be appropriate agenda topics for the Critical Minerals Partnership.

The metals produced from critical minerals are vital ingredients to the U.S. industrial capability. The process of globalization has created a situation where the country relies more heavily on foreign sources of supply for its minerals and metals than ever before. This is not an undesirable situation; in fact it is mostly beneficial to producers and consumers alike. However, critical minerals facing a risk of supply disruption or unavailability would lead to market failure, with potentially dire consequences for the U.S. economy and therefore for its security. In such a case, government intervention is both appropriate and necessary. We have proposed a number of policy recommendations which, if implemented, would reduce the risk to the U.S. of a supply disruption in critical minerals.

Article I. Metals Essay

Throughout our study of strategic materials the seminar has looked at a full range of issues associated with the metals from occurrence in the earth's crust to final products. In keeping with the overall theme of the paper, this essay will address three groups of minerals that the seminar identified as either strategic – titanium; or critical – beryllium and rare earth elements. These minerals share many characteristics with the other minerals evaluated in the Critical Minerals and the U.S. Economy report and encompass the myriad of issues facing the industry including access, the impact of globalization and substitutability.

Titanium

Rutile ore is primarily mined in Australia (50% of world production) followed by South Africa with 28%, Ukraine with 14% and India with 4%.⁴¹ U.S. production is negligible, largely due to the lack of identified economic deposits and the difficult regulatory environment. There are many global mining companies and virtually no American firms involved in rutile extraction and beneficiation. However, obtaining rutile ore is a moderate supply risk due to the relative abundance, widespread distribution and political nature of the source countries.

The U.S. imported an estimated 64% of its sponge requirements in 2007. The sources of imported sponge include Kazakhstan (51%), Japan (37%), and Russia (7%), Ukraine (3%), and others (2%).⁴² USGS data projects that domestic sponge capacity will grow from 20K lbs in 2007 to more than 40K lbs in 2012.⁴³

Despite being a net importer of titanium ore and sponge, the U.S. is a net exporter of titanium metal products—producing 54% of the world's ingot.⁴⁴ With eight melted product (ingot or slab) producers and many more milling and fabricating operations⁴⁵, U.S. capacity further along the supply chain is not a major issue. Although capacity is currently constrained, melt facility expansion is occurring.

The titanium market is cyclical and highly dependent upon the boom-bust commercial aerospace market. This cyclical nature tends to make the industry conservative resulting in capacity constraints during the good times. Other trends include China, Kazakhstan & Ukraine moving downstream in the supply chain; increased long term supply agreements; a net import reliance (on ore and sponge) and a continued research for cheaper titanium.

There are no viable substitutes for titanium in aerospace applications in engines or structure with composites. Aluminum does not achieve the same level of corrosion resistance provided by titanium. For non-aerospace applications high strength low alloy steel is a potential substitute, however there is a trade off in weight.

In summary, there are no significant barriers to access rutile or sponge. All sources of import are generally considered stable. The one concern is downstream movement by sponge producers would reduce the amount of sponge available for import. Globalization has thus far not had a negative impact on the titanium industry with regard to access and trade. Substitutability is the greatest challenge as there are no viable substitutes for titanium in the aerospace industry.

Beryllium

Due to superior physical, mechanical, and nuclear properties including its light weight (weighs 2/3 that of aluminum), stiffness (six times that of steel), strength, temperature resistance,

non-magnetic qualities and reflectivity beryllium is sought for use in a wide range of both commercial and defense related products. Due to the nature of the defense related products, beryllium, by many observers, is considered both a critical and strategic material.

Perhaps the earliest and best known use of beryllium is its use in nuclear weapons. Other defense uses include nuclear reactor neutron reflectors, aircraft disc brakes, rocket propellants, satellite structures, aircraft engine parts, submarine cable housings and pivots, and non-sparking tools to name a few. It is used in high technology ceramics and can be found in armor for vehicles. There are no suitable substitutes for beryllium in most defense applications.

The U.S. is one of three countries known to process beryllium ores and concentrates into beryllium products. The other two are Kazakhstan and China. Of the three, the U.S. is the greatest producer accounting for 85% of the world's production in 2005.⁴⁶

Although the U.S. sits on 65% of the world's reserves, it was not until 1969 that the U.S. mined bertrandite ore and produced its own beryllium products. Up until that time, we were a net importer. With the previous statistics in mind, some may question beryllium's criticality, since it is an abundant domestic resource.

It is not the accessibility of bertrandite, but the process of converting the ore to beryllium hydroxide [Be(OH)₂], the primary feedstock for metallic beryllium, beryllium alloys and beryllia ceramics that makes the metal critical. In 2000, the only beryllium processing plant in the U.S. was shut down by its owner, Brush Wellman. The 2005 USGS Minerals Yearbook noted that a factor in the 2000 closure was the availability of beryllium from the National Defense Stockpile. This availability, along with environmental requirements on the old plant, contributed to Brush Wellman's decision to close the plant as uneconomical.

The House Armed Services Committee questioned the supply and assured future access of high quality beryllium. Brush Wellman was granted a total of \$75 million under Title III of the DPA in 2004 to reestablish this production capability. The new facility is expected to be operating by 2010.⁴⁷

Beryllium will continue to be a strategic material as we continue to find new applications for the material in defense, energy, and aerospace products. However, beryllium will not be considered a critical mineral in the future once the domestic capacity for processing ore is functional, that having mitigated the supply risk.

Rare Earth Elements

Rare earths are a group of 17 elements comprising scandium, yttrium and the lanthanides. In rock forming minerals rare earths typically occur in compounds such as carbonates, oxides phosphates, and silicates. The three common ores containing rare earths are monazite, found in Australia, bastnasite, found in California and China, and xenotime, found in Southeast Asia.⁴⁸

In 2000, one mining operation in California accounted for all U.S. domestic mine production of rare earths. Molycorp (Chevron Mining Inc.) mined bastnasite by open pit methods at Mountain Pass, California. Mine production was estimated to be 50,000 metric tons of rare earth ore (REO). Operations were suspended in 2002 for environmental reasons. Molycorp has all permits in place, including a 30-year mining permit, and expects to resume mining in 2010 with full operations by 2012. Molycorp anticipates strong sales based on strong demand from rare earth magnet manufacturers. Domestic consumption of rare earths has increased significantly from past years due to demand for permanent magnets and rechargeable batteries. The approximate distribution of REO is as follows: automotive catalytic converters, 39%; permanent magnets, 22%; glass polishing and ceramics, 16%; petroleum refining catalysts,

12%; metallurgical additives and alloys, 9%; rare earth phosphors for lighting, televisions, computer monitors, radar, and x-ray films, 1%; and miscellaneous, 1%.⁴⁹

Indications are that China is the leading producer and consumer of REE. Some key points to recap:

- World reserves of rare earths were estimated by the USGS to be 100 million metric tons. China, with 30.9% had the largest share of those reserves.
- China has 91.7% of the REE production. The U.S. has no RRE production until the Molycorp (Chevron Mining) mine comes back online in 2010.

Civilian applications continue to grow at an amazing pace. Current technologies include automotive catalytic converters; metallurgical alloys; ceramics; phosphors; petroleum refining catalysts; magnets; cell phones (ceramic magnetic switches), and nuclear energy.

High energy magnets have special significance for use in military applications. These magnets are grouped into the following two categories: (1) those which the magnet generates force influencing motion. Examples are linear actuators on flight control surfaces, motors, generators, and disk drives and (2) electronic devices in which a magnet generates a field that affects a stream of electrons. Examples are power devices which generate beams of micro waves; linear induction accelerators, and high powered electron lasers.⁵⁰

These three metals provide specific examples of strategic and critical materials. These examples are a microcosm of the issues such as import dependence, substitutability, and globalization confronted when coordinating minerals policy.



Article II. Acquisition Essay

This study found that DoD faces some serious challenges regarding strategic materials and critical minerals. The Department should begin considering these challenges within the overall acquisition environment. While the concerns extend beyond DoD, the department must take the lead and reposition itself in a globalized economy, where certain materials and minerals needed for defense are often difficult to obtain, expensive and hard to substitute. Unaddressed, these factors will continue to adversely impact the operation of the defense acquisition system, and challenge the successful outcomes of individual acquisition programs. DoD can address these challenges through the department's existing acquisition framework and its established decision support systems, beginning with the Joint Capabilities Integration and Development System (JCIDS).

Materials-Focused Requirements

The Chairman of the Joint Chiefs of Staff Instruction 3170.01E guides the operation of the JCIDS⁵¹, which is the requirements generating portion of the defense acquisition system. Within JCIDS, DoD develops and validates all of its capabilities needs and requirements. As an essential input into the acquisition process, well-defined requirements ensure that the department defines and understands its needs in terms of operational capability gaps, risks and opportunities. Similarly, DoD can also use JCIDS to better understand its materials needs, by conducting materials-focused assessments throughout the process. By doing so, DoD could identify the extent to which strategic materials drive its requirements. Such insight would help to validate pursuing either doctrinal change requirements that have little or no materials impacts, or pursuing new materiel requirements that have significant materials impacts.

DoD should also use JCIDS to better define its desired capabilities in terms of weight reduction goals, ballistic protection levels, affordability, and any other materials-driving attributes and characteristics. By doing this, the department will better select among its materials alternatives based on cost, performance, schedule and other constraints. This would address some of the recommendations made in recent NRC reports regarding DOD's materials management in two important ways: First, through JCIDS DoD can fully involve its engineering and research laboratories to define materials requirements, in terms of technical availability and feasibility. Second, through the knowledge management information system within JCIDS, the department can collect and share key materials information throughout the enterprise. Adopting these steps will result in more accurate and complete definitions of the department's materials needs, enhancing its ability to develop materials-focused lifecycle acquisition and support strategies.

Materials-Focused Programs

The DoD 5000 series publications guide the operation of the defense acquisition system.⁵² Through this system the department translates its valid requirements into lifecycle acquisition and support strategies that guide programs, as they pursue materiel solutions. Within today's acquisition environment, there is a change in emphasis for meeting the department's needs, from pursuing unique defense solutions, to adopting available commercial solutions. The department's strategies should reflect this new emphasis in terms of materials considerations.

For example, a ground combat vehicle program might decide to meet a survivability requirement using ballistic armor made from either rolled homogeneous steel at a cost of \$1.00-3.00 per pound, or by using aerospace grade titanium alloy at a cost of \$30.00-50.00 per pound.

The existing defense acquisition system offers a sound method for making materials-focused program decisions. Since the system relies on integrated product and process development, DoD should establish a materials integrated product team to guide its acquisition programs. The materials Integrated Product Team (IPT) must be cross-functional with the systems engineering, lifecycle logistics, business and other IPTs. The materials IPT must be able to interpret all available materials information from industry, defense and US government sources (such as the USGS). By doing so, DoD will begin to address the criticality, supply and substitutability concerns that the NRC outlined within its reports, by documenting specific materials choices related to its acquisition objectives. DoD will also be able to resolve materials issues earlier in the acquisition lifecycle. After establishing materials-focused acquisition programs, the department must also be able to estimate materials costs and affordability.

Materials-Focused Cost and Affordability

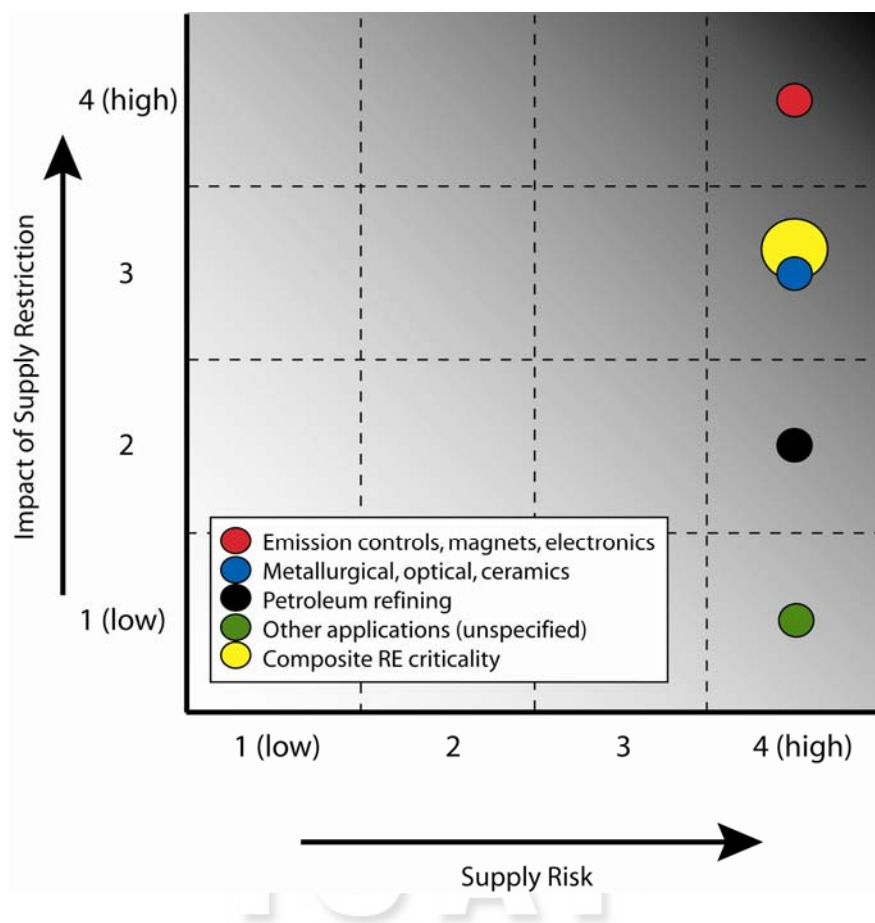
The DoD Planning, Programming, Budgeting and Execution (PPBE) process is the department's resource allocation system.⁵³ While all PPBE elements apply to materials, the budgeting element is most important for the department's acquisition process in two ways. First, DoD must ensure that its acquisition program cost estimates include all aspects of their materials-focused requirements and strategies. Estimates should also consider the materials costs throughout the acquisition lifecycle, so that they include all materials needed to develop, acquire, field and sustain the capabilities that programs deliver.

Second, DoD must develop a materials-focused budget, with R&D, procurement, and operations and support materials affordability goals. This would allow the department to begin to integrate materials investments within the overall defense budget. It would also guide materials investment decisions throughout the enterprise, in concert with the defense acquisition system. This is especially important if materials choices result in higher program costs, as they would by using titanium armor instead of steel. Finally, through its budget, DoD could also address concerns regarding materials investments, and begin to secure resources necessary to execute its materials strategy.

Summary

DoD faces strategic materials and critical minerals challenges that threaten its acquisition objectives. The most significant and solvable challenges include materials-focused requirements definition, acquisition program design and resourcing. The department can begin to address all these challenges through its existing acquisition framework and decision support systems. By doing so, DoD would improve the operation of the overall defense acquisition systems and the outcomes of its individual acquisition programs. These improvements would provide DoD a better understanding of its materials requirements, and greater insight into its materials risks in terms of availability, cost, substitutability and supply disruptions. The department can use the insights of materials-focused strategies to meet its needs, rapidly transition new technology and achieve lifecycle outcomes. Finally, the department will begin to make better materials investments, through materials-focused cost estimates and affordability assessments that fully integrate materials considerations into the defense acquisition system.

Figure 1. Criticality Matrix



(Source: NRC, Minerals, Critical Minerals and the U.S. Economy)

End Notes

- ¹ Minerals, Critical Minerals, and the U.S. Economy, 20.
- ² Ibid.
- ³ Managing Materials for a 21st Century Military, 6-3.
- ⁴ Hedrick, "Rare Earths," *Mineral Commodity Summaries 2008*, 134.
- ⁵ Minerals, Critical Minerals, and the U.S. Economy, 89.
- ⁶ Benfield, "Mountain Pass Mine Update," 1-10.
- ⁷ Molycorp, "Molycorp to Restart Mountain Pass Rare Earth Operations This Year," April 25, 2007.
- ⁸ Reuters, "Evraz wins EU conditional OK to buy Highveld," February 20, 2007.
- ⁹ DoD Memo, "Department of Defense List of DX-rated Programs," November 7, 2007.
- ¹⁰ Velocci, "Minerals: The Resource Gap," 35.
- ¹¹ King, "The Secret of the Missing Stockpile," 1.
- ¹² Ibid.
- ¹³ OTA, *Strategic Materials: Technologies to Reduce U.S. Import Vulnerability*, 91.
- ¹⁴ Ibid., 94.
- ¹⁵ Ibid., 83.
- ¹⁶ Ibid., 97.
- ¹⁷ USC, Title 10, Section 2533a.
- ¹⁸ Aerospace America, "Buy American and the Berry Amendment," September 2006, 26.
- ¹⁹ The first two tiers of the supply chain usually refer to the prime contractor and its major subcontractors. For example...Lockheed Martin would be the 1st tier for the F-22 and Pratt & Whitney (engines) would be one of the second tier contractors.
- ²⁰ USC, Title 10, Section 2533b.
- ²¹ Brush Wellman started receiving cost-share funding through DPA Title III in 2005 for the design of a new production facility.
- ²² Benfield, "Mountain Pass Mine Update," 1-10.
- ²³ DARPA, "DARPA Initiative in Titanium."
- ²⁴ Cammarota, DoC briefing to ICAF on 31 March 2008.
- ²⁵ Ibid.
- ²⁶ Reduction in production at California's Mountain Pass mine due to regulatory and environmental issues has meant increased reliance on China for REEs. REEs are cheaper to mine in China due to lower labor and regulatory costs. While this dependence will end in 2012, the current dependence on China may mean a loss of U.S. leadership in REE technology advances. Dependence comes at a bad time, as REEs are becoming increasingly important to defense applications. From Haxel, U.S. Geological Survey, Fact Sheet 087-02.
- ²⁷ Fluorspar is necessary in the production of computer chips.
- ²⁸ Cammarota, DoC briefing to ICAF on 31 March 2008.
- ²⁹ Ibid.
- ³⁰ There is an assumption at some U.S titanium producers that increase in titanium production will be fueled by growing world gross domestic product. A certain amount of that growth will be driven by the commercial aerospace industry (i.e. Boeing's Dreamliner will require 2.5 times the titanium than its 777 model did).

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- ³¹ Gambogi, USGS briefing to ICAF on 20 March 2008.
- ³² Raulston, National Mining Association briefing to ICAF on 14 April 2008.
- ³³ Cammarota, DoC briefing to ICAF on 31 March 2008.
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- ³⁵ Economist Intelligence Unit, “Zambia Country profile 2007,” 25.
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- ³⁸ Minerals, Critical Minerals, and the U.S. Economy, 21-23.
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- ⁴¹ Gambogi, “Titanium,” *Mineral Commodity Summaries 2006*, 179.
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- ⁵¹ For more information, see the Chairman of the Joint Chiefs of Staff Instruction 3170.01E.
- ⁵² For more information, see the Department of Defense Directive 5000.1 and DoD Instruction 5000.2.
- ⁵³ For more information, see the Department of Defense Planning, Programming, Budget, and Execution (PPBE).

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