THE UNITED STATES' VULNERABILITY TO COERCION BY CHINA IN THE RARE EARTHS MARKET

A thesis presented to the Faculty of the U.S. Army
Command and General Staff College in partial
fulfillment of the requirements for the
degree

MASTER OF MILITARY ART AND SCIENCE
General Studies

by

WILLIAM D. HOBBS, MAJOR, U.S. ARMY
B.S., University of Arizona, Tucson, Arizona, 2001

Fort Leavenworth, Kansas
2012-02

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
14-12-2012

2. REPORT TYPE
Master's Thesis

3. DATES COVERED *(From - To)*
FEB 2012 – DEC 2012

4. TITLE AND SUBTITLE
The United States' Vulnerability to Coercion by China in the Rare Earths Market

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
MAJ William D. Hobbs, USA

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Command and General Staff College
ATTN: ATZL-SWD-GD
Fort Leavenworth, KS 66027-2301

8. PERFORMING ORG REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for Public Release; Distribution is Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This thesis looks at the importation of rare earth elements which are considered vital to the security of the United States (U.S.) and are used to manufacture products for the U.S. defense industry. The purpose of this thesis is to answer the primary research question: Has the U.S. allowed itself to be placed in a position within the world economy which makes it vulnerable to coercion by another world actor, such as a foreign nation or super corporation?
In order to answer the research question it was first necessary to identify why rare earth elements are so critical to key strategic programs within the defense industry. An additional analysis of where the world's rare earth mineral reserves are located and which nations are mining rare earths would identify weaknesses or strengths within the global supply chain. The supply chain for which the U.S. receives their rare earth elements and processed products was then tracked and analyzed in order to identify any vulnerability. Once a possible vulnerability was identified the research explores whether the U.S. Government had taken steps to mitigate the risks to the defense industry. The research shows that there is vulnerability in the U.S. supply chain for rare earth elements due to a single source supplier that is not a nation allied to the U.S. Solutions to this problem are currently being addressed by both the U.S. Government and the defense industry. A second and possible third source for rare earth minerals is currently on track to be operational by FY2013.

15. SUBJECT TERMS
Rare Earths, Economic Coercion, China, Strategic Materials Security Program, National Defense Stockpile

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. PHONE NUMBER** *(include area code)*
(U)	(U)	(U)	(U)	97	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

MASTER OF MILITARY ART AND SCIENCE

THESIS APPROVAL PAGE

Name of Candidate: Major William D. Hobbs, USA

Thesis Title: The United States' Vulnerability to Coercion by China in the Rare Earths Market

Approved by:

____, Thesis Committee Chair
David A. Anderson, DBA

____, Member
James R. Cricks, M.A.

____, Member
Timothy J. Brown, M.S.

Accepted this 14th day of December 2012 by:

____, Director, Graduate Degree Programs
Robert F. Baumann, Ph.D.

The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

THE UNITED STATES' VULNERABILITY TO COERCION BY CHINA IN THE RARE EARTHS MARKET, by Major William D. Hobbs, USA, 97 pages.

This thesis looks at the importation of rare earth elements which are considered vital to the security of the United States (U.S.) and are used to manufacture products for the U.S. defense industry. The purpose of this thesis is to answer the primary research question: Has the U.S. allowed itself to be placed in a position within the world economy which makes it vulnerable to coercion by another world actor, such as a foreign nation or super corporation?

In order to answer the research question it was first necessary to identify why rare earth elements are so critical to key strategic programs within the defense industry. An additional analysis of where the world's rare earth mineral reserves are located and which nations are mining rare earths would identify weaknesses or strengths within the global supply chain. The supply chain for which the U.S. receives their rare earth elements and processed products was then tracked and analyzed in order to identify any vulnerability. Once a possible vulnerability was identified the research explores whether the U.S. Government had taken steps to mitigate the risks to the defense industry. The research shows that there is vulnerability in the U.S. supply chain for rare earth elements due to a single source supplier that is not a nation allied to the U.S. Solutions to this problem are currently being addressed by both the U.S. Government and the defense industry. A second and possible third source for rare earth minerals is currently on track to be operational by FY2013.

ACKNOWLEDGMENTS

I would first and foremost like to acknowledge God for blessing me with such a wonderful family and life. I would like to thank my wife Mollie from the bottom of my heart for supporting me through this long process. I wish also to acknowledge the outstanding tough love that Dr. David Anderson provided me along the way. Without his guidance, advice, and motivation I truly would not have been able to finish my thesis. To Mr. Cricks and Mr. Brown, thank you for your instruction this year, you both are outstanding teachers and mentors, and I learned a great deal this year.

TABLE OF CONTENTS

ACRONYMS

AMP	Annual Materials Plan
DLA	Defense Logistics Agency
DoD	Department of Defense
DSCS III	Defense Satellite Communication System III
EHF	Extreme High Frequency
EU	European Union
GATT	General Agreement on Tariffs and Trade
IDA	Institute for Defense Analyses
NAVSTAR	Navigation Signal Timing and Ranging Global Positioning System
NDS	National Defense Stockpile
OPEC	Organization of the Petroleum Exporting Countries
QDR	Quadrennial Defense Review
SHF	Super High Frequency
SMPB	Strategic Materials Protection Board
SMSP	Strategic Materials Security Program
TWT	Traveling Wave Tube
U.S.C.	United States Code
USGS	United States Geology Service
USMMA	United States Material Management Agency
WTO	World Trade Organization
YSZ	Yttria-Stabilized Zirconia

ILLUSTRATIONS

CHAPTER 1

INTRODUCTION

> China continues to make its export restraints more restrictive, resulting in massive distortions and harmful disruptions in supply chains for these materials throughout the global marketplace.
>
> — Ron Kirk, *The Christian Science Monitor*

Background

Over the last three decades the global economic system has been going through a massive transformation. Countries from all parts of the world are now trading with each other in very diverse ways. At one time only a few select nations had the ability and means to trade in large quantities of goods. This type of trade is now commonplace for almost all nations. The world’s economy has become so intertwined and interconnected that when a stock market in one region of the world closes for the day with a net loss or gain, it is almost guaranteed that the remaining regional stock markets will be affected either positively or negatively by the news.

The manufacture of goods in today’s market is no longer necessarily a single national effort. For example, part A for a liquid crystal display screen is made in one country, part B for a computer hard drive is from a second county, and the product itself, a computer, is assembled in a third country. This has brought down the total cost of such products which has had very positive effects on the world’s economy. When materials or resources can be obtained from multiple sources around the world, costs of procurement and manufacture are lower, which results in the total cost of goods being overall less expensive. Sometimes there is the possibility of a very dangerous side effect from relying on other nations for key goods or resources. When a nation is a leading or sole producer of a scarce resource and tries to manipulate the world market for this resource in order to gain an advantage over other nations, it can result in a real and possibly dangerous conflict.

The world first experienced this type of situation in 1973. The Organization of Arab Petroleum Exporting Counties (OPEC) which was responsible for 55 percent of the world's oil production placed an oil embargo on the United States (U.S.). At the time, the U.S. imported 27 percent of its crude oil requirements, and other Western counties imported 85 percent of their crude oil requirements. This oil embargo was placed on the nations who supported Israel during the 1973 Yom Kippur War. OPEC used this oil embargo to coerce the U.S. into using its influence with Israel to move the Israelis out of the Sinai and broker a Middle East peace deal. The oil crisis of 1973 affected the U.S. economy so negatively that it set in motion a recession which had not been experienced since the Great Depression. It took almost a decade for the U.S. economy to recover. OPEC has been able to dominate the world's oil markets and keep oil prices high in order to maximize its members' wealth and income. Forty years later, OPEC still has the ability to influence world oil markets.[1]

Another example of economic coercion by restricting access to a scarce resource is when the Russian natural gas giant Gazprom shut off natural gas supplies to Europe in the winter of 2009. Gazprom and the government of Ukraine could not reach a deal on the fixed price that the Ukrainian government was willing to pay for the next year. The

[1]Sarah Horton, "The 1973 Oil Crisis," Brandi Winck, Aerial Communications, www.envirothonpa.org/documents/The1973OilCrisis.pdf (accessed 25 May 2012).

main gas line between the Russian suppliers and the European Union (EU) flows through the Ukraine. When Russia stopped the supplies to that line Bulgaria, Croatia, the Czech Republic, Greece, Italy, Macedonia, Romania, Serbia, Slovakia, Slovenia and Turkey were completely cut off; and supplies to Germany, Hungary and Poland were reduced. The issue was so severe that the national security councils of several European nations convened meetings to discuss how to resolve the vital issue of providing heat to their citizens during the cold winter. The Russians effectively used their gas resource to coerce the EU president and their high commissioner to press the Ukraine into a settlement.[2]

The case filed in the World Trade Organization (WTO) against China by the U.S., Japan, and the EU is a more recent example of economic coercion by restricting access to rare resources.[3] The case involved a group of minerals referred to as rare earths. These rare earths are comprised of 17 different elements: Scandium, Yttrium, Lanthanum, Cerium, Praseodymium, Neodymium, Promethium, Samarium, Europium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium, Yterbium, and Lutetium. Rare earth minerals are utilized in the manufacture of some of the world's most vital technology such as computer hard drives, smart phones, and rechargeable batteries. These items are used in everything from computers to hybrid cars. Rare earths are also an important part of the U.S. defense industry and future plans for a renewable energy program.

[2]BBC News Europe, "Russia Shuts Off Gas to Ukraine," 1 January 2009, http://news.bbc.co.uk/2/hi/europe/7806870.stm (accessed 16 April 2012).

[3]CNN Wire Staff, "Obama Announces WTO Case Against China Over Rare Earths," CNNNews, 13 March 2012, http://www.cnn.com/2012/03/13/world/asia/china-rare-earths-case/index.html (accessed 16 April 2012).

The U.S. was one of the world's leading producers of rare earths until the 1990s.[4] Starting in the mid-1980s China began to mine rare earths, and by 1990 China's production of rare earths surpassed that of the U.S. China utilized their high production rate for rare earths to flood the market and force the price down so low that other world producers could no longer mine these elements and remain profitable. Once China had forced out all other producers of rare earth minerals, they effectively gained control of the world's only cost efficient supply of rare earths. During the following two decades the demand for rare earths skyrocketed around the world. Technology in computers, hybrid cars, and metallurgy has become even more reliant on rare earths. The special properties they bring to manufacturing processes cannot easily be synthesized by other means.

As the world has become extremely reliant on rare earths for some of its highly technical specialized manufacturing, China has slowly been using their control of these minerals to draw global manufacturing of high tech goods in great demand away from the countries that currently produce them and move them to China. To achieve this goal, China has started placing a quota on the export of rare earths, while continuing to fully supply their domestic manufacturing base. China's main targets were countries like Japan, South Korea, the U.S. and Europe.

China again used their complete control of the rare earths market in September 2010 when they coerced Japan during a territorial dispute over the Senkaku Islands. The government of Japan arrested the captain of a Chinese fishing boat in the waters of the Senkaku Islands. Both China and Japan claim these islands as their own. The Japanese

---

[4] James B. Hedrick, "Rare-Earths Industry Overview & Defense Applications," U.S. Geological Survey, Reston, VA, 18 February 2005, 34.

government wanted a trial under Japanese domestic law because this would strengthen their claim to the islands by showing that they have legal domain over them and undermining any claim that China might have. China had two choices; to use military action against Japan over the disputed islands, or use their economic advantage with rare earths to force Japan to release the fishing boat captain. On 24 September 2010 China suspended all exports of rare earth minerals to Japan, knowing that this would severely hurt Japan's manufacturing sector. On 24 September 2010, Japan announced that it was releasing the fishing boat captain without trial.[5]

Primary Research Question

In this world of ever increasing globalization and economic interdependency of nations, is it possible for a nation with strategic natural resources to coerce the U.S. into changing its national security policy in order to secure resources?

Secondary Research Question

In order to address and support the primary research question, it is necessary to answer the following secondary questions:

1. Which natural resources can be defined as "strategic" for the U.S. defense industry in support of the military?
2. Which of the defense industries "strategic" resources are controlled by a potential adversary?

[5]Associated Press, "China Halts Rare Earth Exports to Japan Amid Tensions over Territorial Dispute, Traders Say," Fox News, 24 September 2010, http://www.foxnews. com/world/2010/09/24/china-halts-rare-earth-exports-japan-amid-tensions-territorial-dispute-traders/ (accessed 10 May 2012).

3. Are the resources defined as “strategic” because of their economic impact on defense companies or because of their impact on the defense industry’s ability to support and supply the U.S. military?
4. Are there possible alternatives that may be utilized in place of the “strategic” resources for military applications?
5. What are the possible consequences if the U.S. fails to meet its needs for these “strategic” resources?

Purpose

The purpose of this study is to examine the possibility of identifying any unknown points of vulnerability that the U.S. might have; or if a point of vulnerability has previously been identified, have the proper measures been taken to mitigate these vulnerabilities?

Scope

The realm of what one might define as a natural resource is vast. It can be raw unprocessed earth elements, it can be an ore refined into a precious metal. One might even define the skilled population of a nation as a natural resource. For the purposes of this study, the scope will be limited to elements occurring in nature.

Significance

The U.S. economy is the largest in the world. U.S. defense companies are some of the biggest in the world, with an extremely large number of subsidiaries and parts suppliers. With such a sizable supply chain, it is easy to imagine that not every source of natural resources has been vetted to determine the effects if the U.S. defense industry were restricted from access to these supply sources. Failure to identify these possible shortcomings, could lead to the U.S. military being unable to meet requirements for future conflicts.

Assumptions

There are three assumptions that will be utilized in this study. The first assumption is that the current *U.S. National Security Strategy* and its defined national vital interests and themes will continue unchanged in the near future.

The second assumption that will be used in this study is that any action taken to coerce the U.S. will occur before any official act of war and use of military force by the U.S.. This assumption is used to narrow the topic since the main purpose of this study is to determine if there are vulnerabilities which could lead to military action or a declaration of force.

The third assumption utilized in this study is that that the current world economic picture will continue to grow as the world moves past the global recession. This assumption will be used as a baseline for world economic growth and assist in defining which nations are currently major economic players or will become major economic players on the world stage in the near future.

Definitions

Coercion as defined by Dictionary.com is "the act of coercing; use of force or intimidation to obtain compliance."[6] Economic coercion can be defined in many ways.

---

[6]Dictionary.com, "Coercion," http://dictionary.reference.com/browse/coercion?s=t (accessed 25 May 2012).

Economic coercion is when one who controls a resource or commodity uses this advantage or control to force or compel another into an action or to refrain from an action in order to gain advantage over someone or something. By definition, in order to be able to exercise economic coercion, one side has to have market power or monopolistic control over a desired or required commodity.

Rare earths are defined as being one of 17 naturally occurring elements found on the periodic table. They are: Scandium, Yttrium, Lanthanum, Cerium, Praseodymium, Neodymium, Promethium, Samarium, Europium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium, Yterbium, and Lutetium. In the literature these elements are also referred to as rare earths, rare earth metals or rare earth oxides. They can be further defined as light rare earth elements and heavy rare earth elements, depending on the atomic weight of the element.

CHAPTER 2

LITERATURE REVIEW

> Increased indebtedness could leave the United States more vulnerable to economic coercion, which might take the form of another nation withholding valuable natural resources or militarily sensitive goods during a conflict over repayment, cutting back purposefully on its holdings of U.S. dollars to inflict economic damage, or interfering directly or indirectly in U.S. attempts to finance its debt.
>
> — Travis Sharp,
> *The Sacrifice Ahead, The 2012 Defense Budget*

Overview

An abundance of literature has been written about economic coercion as a matter of statecraft between nations. In most reports, this act of economic coercion is defined as a form of economic sanction occurring between two nations or imposed on one nation by another or group of other nations trying to exert their will upon the sanctioned nation. This case study focuses on the non-sanctioned practice of economic coercion between nations which export and import natural resources vital to their national security.

Works of literature reviewed in this chapter will be grouped into three areas of research. The first area of research reviews articles and papers pertaining to various historical cases of economic coercion which bring insight to the question of whether or not the U.S. is vulnerable to coercion in this manner. The second area of research reviews government reports and cases filed with the WTO which are classified as economic coercion. The third area of research examines articles, literature, and reports in the area of worldwide natural resource trade with the goal of identifying possible resources that might be used in the context of economic coercion.

Congressional Reports

The first report reviewed is Congressional Research Service Report R41347 entitled "Rare Earth Elements: The Global Supply Chain" and dated 6 September 2011. This report was written at the request of the 112th Congress in order to start a dialog within the *National Security Policy* forum with the current White House administration. The goal was to identify possible areas of vulnerability and determine possible mitigations. The report addresses several topics relevant to this area of study including the area of rare earth minerals.

Congressional Report R41347 brings to the surface the importance of rare earth minerals to the U.S. economy and our national security. According to the information presented in the report, over the 15-year period leading up to September 2011, the U.S. has become 100 percent reliant on the import of rare earth minerals from other countries, with zero rare earth minerals being mined within the U.S.[7] The research also addresses other mineral elements which the U.S. is extremely dependent upon for our economic needs which are obtained from outside resources. For example 100 percent of our manganese is imported.[8] Over 90 percent of elements such as bauxite, platinum, and uranium are imported from foreign sources.[9] The main difference between manganese, platinum, bauxite and the rare earth elements are the number of sources from which the U.S. can obtain the needed amounts of these elements. Manganese, platinum, and bauxite

[7]Marc Humphries, "Rare Earth Elements: The Global Supply Chain," Congressional Research Service Report #41347, 8 June 2012, http://opencrs.com/document/R41347/2012-06-08/ (accessed 25 April 2012), 2.

[8]Ibid., 1.

[9]Ibid.

have multiple sources of supply from several nations around the world, which means that the risk of being coerced by an outside nation is very low.[10]

In the case of the rare earth minerals acquisition for the U.S. defense industry there is a level of vulnerability with the current supply chain. At the time of this Congressional report, China was the only supplier of rare earth minerals to the U.S. According to the data in this report the total global production of rare earth minerals for the year 2010 was 133,600 tons. While in the same period of time the world demand for rare earth minerals was estimated at 136,000 tons, with the shortfall in mining production previously being met by mining above ground stocks. By 2015 the annual global demand for rare earth minerals is predicted to reach 185,000 tons. China's production of rare earth minerals is projected to reach 140,000 tons by 2015, but China's domestic consumption of rare earth minerals is expected to grow from the current level 73,000 to 111,000 according to the Chinese Rare Earth Industry Association. During the same period of time the U.S. Geology Service (USGS) estimates that the demand for products made from rare earth minerals in the U.S. will increase as much as 10 percent a year.

The Congressional report examines current market plans to alleviate some of the production shortfalls being created by China's new exportation limits placed on the export of rare earth minerals. Two companies, Lynas Corporation of Australia with their Mt. Weld mine, and Molycorp of California, with their Mountain Pass mine are projected to produce 40,000 tons of rare earth minerals by the end of 2012, with additional 20,000 tons being produced by the Mountain Pass mine by the end of 2013, to bring the combined produced of both mines to 60,000 tons by 2014. Other new mining projects are

[10]Humphries, 2.

projected to take another 10 years for development before they can produce any significant quantities. Even with this new production, several of the heavier rare earth minerals such as Dysprosium, Neodymium, Erbium, and Terbium are projected to be in short supply which concerns the U.S. Congress. China recently placed export quotas on the amount of rare earth minerals exports which has led to export suppliers choosing to export the more expensive rare earths minerals and decreasing the export of the less expensive minerals in order to maximize profits. This practice has led to a spike in price for the minerals which are exported in smaller quantities.

An increase in the mining of rare earth minerals is only one part of what needs to be done to alleviate the problem. Once the ore is mined, it still has to be processed and refined into a usable form before it ever makes it to the product manufacture. The shortfall in capacity for the entire supply chain of rare earths minerals has to be addressed before the U.S. can move to a position where it is not vulnerable to coercive practices by scrupulous supply sources. In the Congressional report it states that the limited supply chain for rare earth minerals poses a threat to the national security of the U.S. The Congressional report further states:

> With the exception of small amounts of yttrium, rare earths have yet to be included in the strategic materials stockpile for national defense purposes. Generally, strategic and critical materials have been associated with national security purposes. In the Strategic Materials Protection Board's (SMPB) last report (December 2008), the SMPB defined critical materials in this way: 'the criticality of a material is a function of its importance in DOD applications, the extent to which DOD actions are required to shape and sustain the market, and the impact and likelihood of supply disruption. DOD's current position on strategic materials was largely determined by the findings of the SMPB. Many scientific organizations have concluded that certain rare earth metals are critical to U.S.

national security and becoming increasingly more important in defense applications.[11]

Another reason the shortage in rare earth minerals is problematic to the U.S. is the fact that there is only one country that mines and produces key rare earth minerals. This one source supplier along with the rapid growth in demand from current global manufacturing economies will be from the "rise of emerging economies India (population 1.0 billion) and followed by Africa (population nearly 1 billion), South America (population 400 million), and other parts of Asia (nearly 1.5 billion people). Their economies are expected to grow in the coming years which could keep prices under pressure even as new supply comes on-stream."[12]

In the report the researchers look at different ways to handle and deal with the whole supply chain issue. The answer comes from Japan, one of the U.S.'s strongest allies. In recent months, Japan has been a victim of economic coercion by China, when China withheld shipments of rare earth minerals from Japan until they defused a dispute over a fishing boat caught in disputed waters. Japan has shown interest in securing a new non-Chinese source of supply for their rare earth minerals needs. Japan's Sumitomo Corporation has invested $130 million in Molycorp's Mountain Pass mining project.

The second Congressional report reviewed is the Congressional Research Service Report R41744 entitled "Rare Earth Elements in National Defense: Background, Oversight Issues, and Options for Congress" dated 31 March 2011 and written by Valerie Bailey Grasso, Specialist in Defense Acquisition. The first Congressional report was

[11]Humphries, 12.

[12]Ibid.

written for Congress by a Specialist in Energy Policy. Report R41744 was written for Congress with the focus of rare earths within the Department of Defense (DoD) acquisition program in order to identify which critical programs use rare earth elements and if there are any vulnerabilities in the DoD's supply chain. Report R41347 identified the U.S. as a whole was vulnerable to the fact that China controlled the world's rare earth elements market. Report R41744 takes a deeper look at this global rare earths market domination by China and applies this to the U.S. defense industry's ability to provide the required materials needed to maintain the U.S. military

The author uses the incident between China and Japan during which China withheld rare earth minerals shipments to Japan to develop her research questions and apply them to see the impact on the U.S. defense industry. This scenario showed the power that China could exert on Japan in order to coerce the Japanese government into changing their political stance on the detention of the Chinese fishing boat captain. The writer was looking to answer these questions; "Is there a rare earths material vulnerability that will impact national security?" and "What short-term and long-term options might DoD consider in response to the lack of domestic production and China's continued dominance in this area?"[13]

In her analysis and answer to the questions, the author finds that there are vulnerabilities that could adversely impact the DoD if a scenario like the dispute between China and Japan were to happen between the U.S. and China. The report goes on to

[13]Valerie Bailey Grasso, "Rare Earth Elements in the National Defense: Background, Oversight Issues, and Options for Congress," Congressional Research Service Reports for the People #R41744, 31 March 2011, http://opencrs.com/document/R41744/2011-03-31/ (accessed 25 May 2012), 3.

examine some of the root causes for the DoD not previously identifying vulnerabilities and labeling rare earths as strategic and critical materials. These flaws were caused by the Strategic Materials Protection Board's failure to adapt to new and changing economic environments in which the DoD purchased critical materials. Short-term fixes are discussed along with actions that Congress and the DoD have begun in order to determine a long-term answer.

The third Congressional report reviewed entitled "Reconfiguration of the National Defense Stockpile Report to Congress" dated April 2009 was generated to fulfill the requests made by both the House and Senate Armed Services Committees. The intent of the report was to addresses the issues that had been raised in relation to the way the National Defense Stockpile Program was being managed. In this report for Congress the DoD used a two-phased approach to analyze the National Defense Stockpile Program. As part of the first phase the DoD hired an outside reach group called the National Research Council to evaluate how the Defense Logistics Agency (DLA) and the Defense National Stockpile Center operated the National Defense Stockpile Program. The focus of the research and analysis was to determine if the laws that govern the National Defense Stockpile Program were adequate and current enough to deal with the new faster paced global economy.

The report that the National Research Council submitted to the DoD identified what they believed to be major shortfalls within the guidelines governing the program. An entire rewrite of the definitions and information collection models used in the analysis process for the program was recommended due to the fact they were not capable of providing proper material forecasts for future defense programs. Additional deficiencies were noted within the program and its lack of ability to take action to mitigate risks if there were a disruption in the supply chain of a critically needed material. The National Defense Stockpile Program also lacked the ability to identify if a critical material had other majors uses outside of the defense industry which might contribute to supply shortfalls.

In the second phase of the analysis the DoD created a working group with members from all branches of service and several deputy undersecretaries of defense from various offices. The working group also includes members from the USGS and the Department of Commerce. The group recommended five changes to the National Defense Stockpile Program. First, the current policy for disposal of the stockpiled materials needs to be revised. Materials being sold from the National Defense Stockpile were now being identified as strategically important over concerns of the source of supply. Second, the National Defense Stockpile needs to be reconfigured in order to better respond to the rapid changes that can occur within the world markets. Third, expand the definition of critical materials to include all those needed to supply the national security interest and have no domestic production or the source of supply for the materials is a security concern. Fourth, domestic suppliers of critical materials need to have full knowledge of all raw materials coming from foreign sources. Fifth, efforts by foreign counties to stockpile critical materials need to be monitored in order to identify possible market troubles.

In conclusion, the report recommends to Congress that the National Defense Stockpile Program is no longer viable in its current form. The DoD Working Group assessment is that the National Defense Stockpile Program be rewritten under new law to become the Strategic Materials Security Program (SMSP). The new program should have the ability to take action in a timely manner in order to ensure the program has the right strategic materials and is able to respond to current and future needs in a timely manner.

USGS Reports

Every year, the USGS, as part of the U.S. Department of the Interior, publishes a report entitled “Mineral Commodity Summaries.” The “Mineral Commodity Summaries” are detailed reports on the prior year’s events, issues, and trends for mineral production encompassing data from the entire world market. The report provides a two-page synopsis for the top 90 individual minerals and materials used in the U.S. If an individual mineral is listed in the National Defense Stockpile then a detailed status of the quantity of that mineral within the National Defense Stockpile Program will also be listed.

The “Mineral Commodity Summaries” for the years 2010 and 2011 were reviewed for information concerning rare earth minerals. The information provided in both years reports states that 100 percent of the rare earths used in the U.S. were imported. In the area of rare earth minerals the U.S. was 100 percent import dependent with zero domestic mining production. Also, both reports listed that according to U.S. government data there were no rare earths minerals being held within any government stockpile.

Data in the “Mineral Commodity Summaries 2011” report shows an increase in the domestic consumption of rare earth elements over the “Mineral Commodity Summaries 2010” report. According to the data this increase in consumption was a reversal from the annual decline in domestic consumption from 2005 through 2009. Also noted in the 2011 report was a one percent increase in the importation of rare earth elements from China. In 2009 China accounted for the import source from 91 percent of the total rare earths received in the U.S. With the increase in consumption came an increase in the total importation of rare earths from China from 91 percent to 92 percent of the U.S. totals. The remaining rare earths were imported from France, three percent; Japan two percent; Austria, one percent, and two percent from other countries.

DoD Reports

The Institute for Defense Analyses (IDA) provided the DoD with a report in May 2010 entitled *From National Defense Stockpile (NDS) to Strategic Materials Security Program (SMSP): Evidence and Analytic Support*, *Volume I.* The IDA report was to provide an analysis of the DoD's recommendation to change the National Defense Stockpile Program to the SMSP. The analysis used the requirements and process that the DoD planned to use in the future of the SMSP.

The IDA report had three tasks from the new SMSP program which they were to evaluate and then report on the findings from the analysis conducted. The first task was to look at the requirements process the DoD developed in order to identify which materials are deemed necessary to stockpiling along with possible risk mitigations. Task two of the report used the new processes to identify standard and specialty materials requiring attention by the Secretary of Defense. The third task was to collect supply and demand data on the materials identified in task two in order to develop market models that the DoD could use to enhance the purchase of these materials.

The IDA report made several recommended changes to the SMSP. Some of the key changes recommended were expanding the scenarios used to encompass a wider range of possible scenarios. A more indepth analysis of the total supply chain for critical weapons system programs to insure all requirements for materials were identified and any possible risks could be mitigated. The report also identified the need for more studies into the uses of critical materials by both the DoD and the private sector. These studies should also look at the feasibility of possible alternatives to the listed critical materials. The final recommendation was for continued analysis of the SMSP from multiple perspectives to help ensure the program continues to evolve to meet the strategic needs of the U.S.

The next DoD report reviewed entitled *Strategic and Critical Materials Operations Report to Congress: Operations under the Strategic and Critical Materials Stockpiling Act during the Period October 2009 through September 2010* prepared by the Under Secretary of Defense for Acquisition, Technology and Logistics Office was dated January 2011. This DoD report is submitted annually to Congress in order to provide a summary of the previous year's events, trends. and actions of the National Defense Stockpile Program. A review of this report was conducted to gain an understanding of the past, present, and possible future of the Strategic and Critical Materials Stockpiling Program.

Section one of the report gives an overview of the "Strategic and Critical Materials Stock Piling Act" (50 U.S.C. 98 et seq.) and Appendix A provides a copy of the law defining the intended purpose of the program. As part of the overview the report gives an account of the programs history during the 1990s and 2000s. During the 1990s, the DoD made the determination that almost the entire National Defense Stockpile was no longer needed. Congress then authorized the disposal of 99 percent of the materials held in the National Defense Stockpile. Appendix B thru D of this report provides excerpts forom the past "National Defense Authorization Acts" pertaining to the sale of materials from the National Defense Stockpile and the disposition of the funds from the sale. The excerpts show how Congress transferred billions of dollars in funds out of the National Defense Stockpile Program into other programs.

Section two of the report addresses the Annual Materials Plan (AMP) for FY 2010 which governs the amount and type of materials to be sold or purchased during the fiscal year. Table one of this section provides a list of the materials identified in the FY 2010 AMP. The report states that no materials have been purchased for the National Defense Stockpile since 1997. As part of the sale of materials deemed no longer required in the National Defense Stockpile the program has sold $6.23 billion dollars' worth of materials from 1996 to 2010.

Section three of the report provides an overview of the financial status of the National Defense Stockpile transaction fund. According to the report the program in FY 2009 had $1.7 billion in unobligated funds of which $1.3 billion was transferred by Congress to other accounts. In FY 2010, $196 million in materials were sold from the National Defense Stockpile with Congress transferring $71 million to other outside accounts leaving the program with $417 million in unobligated funds.

As part of a series of reports requested by Congress from the DoD in response to updating or changing the "Strategic and Critical Materials Stock Piling Act", the DoD submitted the report *Strategic and Critical Materials 2011 Report on Stockpile Requirements.* This report was prepared in January 2011 by the Under Secretary of Defense for Acquisition, Technology and Logistics. This report continues to evaluate and expand on the earlier reports to Congress focusing on the vulnerabilities with the current scenario models used to determine which materials are strategic and critical to national defense. In addition, the DoD used a new approach developed for the new SMSP to analyze the data in order to align the models to incorporate the requirements used by the Secretary of Defense in budgeting and planning. Attention was given to insure the new planning models aligned with latest *National Defense Strategy* and the *2010 Quadrennial Defense Review (QDR).*

The new models used realistic scenario data to project supply chain conditions and demands for key strategic materials in order to develop a time phase projection in order to identify any shortfalls or points of vulnerability. The report then uses the data collected from the projected shortfalls to develop a new list of materials needing risk mitigation plans. Chapters one and two of the report cover the running of the new scenarios and the development of the critical materials lists derived from the data collected in the scenarios. Chapter three uses the data collected on the critical materials in order to develop realistic solutions to mitigate the risks identified in each scenario.

After running the new models, 70 materials were flagged for further analysis. Of the 70 materials labeled, 28 were identified to have shortfalls that needed development of risk mitigation strategies. Seven rare earth elements were identified as critical materials and needed to have a mitigation strategy developed. All seven rare earth elements were identified as shortfalls with no materials currently being stored as part of the National Defense Stockpile.

The DLA also published the “2012 Director’s Guidance” revised April 2012 for the DoD. The DLA’s first guidance was released in January 2012 but revised three months later in order to allow the director to clarify issues that had been identified with the new defense strategy and joint operating environment during the previous year. The director wanted to emphasize his main themes and provide measures of performance in achieving the department's goals for transparency and accountability. The guidance is formatted by function within the DLA and then divided into task and subtasks that need to be achieved by that section.

For the purposes of this report the research was focused on warfighter support section WS-6 entitled Enhance DLA Strategic Materials program to meet emerging support requirements. This section has three main tasks and six subtasks as part of the DLA Strategic Materials operation requirements. Task one: complete the implementation plan for the transformation of the DLA Strategic Materials program and obtain congressional approval to streamline select National Defense Stockpile (NDS) processes. Task two: complete the rare earths study to identify critical materials warranting strategic inventory support. Task three: partner with other departments and agencies to address additional strategic materials issues and develop risk mitigations strategies.

American Security Project Report

The American Security Project published a report "Rare Earth Metals and U.S. National Security" by Emily Coppel dated 1 February 2011. In this report the author's main point echoes the same alarm that most reports in 2011 where signaling. The analysis in the report shows that at current rates of consumption matched with current rates of mining and processing, there will be a shortfall or shortage of rare earth minerals required to meet the world demands.

The American Security Project report claims that the U.S. defense industry and other military application of commercial equipment like cell phones and laptops have become too dependent on China to meet the needs of a critical part of the *U.S. National*

Security Policy. Former DoD trade advisor, Peter Leiter is quoted as saying "the Pentagon has been incredibly negligent . . . there are plenty of early warning signs that China will use its leverage over these materials as a weapon."[14] According to the report, the U.S. assured the Chinese dominance of the rare earth minerals when the Mountain Pass mine in California closed in the early 1990s and the production capabilities were sold making the U.S. dependent upon rare earth minerals imports. The report states that this near-monopoly of production in rare earths has led to an average cost increase of 31 percent for nations importing rare earth minerals in their production cost than companies within China who use the same rare earth elements.

The report gives several recommendations to help solve or alleviate the problem with China's control over such an unknown key element to our nation's economy and our military defense. The first course of action is to reinstitute the rare earth minerals back into the National Defense Stockpile. Rare earths have not been a part of the defense stockpile since 1998. This would not solve the problem but would give the nation time to figure out other possible solutions. The second recommendation is to reestablish American mines and start refining and producing our own rare earths resources. According to the USGS, the U.S. has the third largest reserves of rare earth minerals in the world.

Further recommendations include filing a dispute with the WTO for placing export quotas on rare earth minerals while the Chinese government stockpiles tens of thousands of metric tons. The writer also feels that through international cooperation,

[14]Emily Coppel, "Rare Earth Metals and U.S. National Security," American Security Project, 1 February 2011, http://americansecurityproject.org/reports/2011/not-so-rare-earths-2/ (accessed 25 May 2012), 3.

nations that are currently dependent upon China for their rare earth minerals needs should form a joint venture in the development of other sources of rare earth mining and production outside of China. The report even goes so far as to recommend that nations could form an alliance or treaty pact allowing nations to work closely together to further alleviate shortages through cooperation agreements.

The report's two final recommendations are currently the most difficult to solve. Rare earth minerals currently have no suitable substitute. When rare earth minerals are substituted in manufacturing processing of current military grade weapons or equipment there is a loss in performance that is not acceptable, and there is a failure to meet defense industry standards. The only option currently available is to invest in research to either find suitable substitutes or increase the efficiency of current production methods to reduce the total quantity necessary to manufacture the required rare earths.

The conclusion of the report is that through domestic mining and production the U.S. needs to develop a comprehensive plan that reduces the nation's dependence on Chinese exports of rare earth minerals. The U.S. needs to invest in new technologies that either reduce the use of rare earths minerals or improve the performance of current technologies to maintain our advantage over our competitors.

U.S. Material Management Agency (USMMA) Report

In October 2010 the USMMA conducted an assessment for the DoD on the current supply chain and uses of rare earth elements within the defense industry. The report looked at known key defense systems within the military that use rare earth elements and currently have no known suitable substitute. The report provides its limitations to main components of a defense system and states that subsystems assemblies may also contain rare earth elements but the report does not go into great detail.

The USMMA report gives a broad overview of the DoD's known supply chain for the components that will be listed under each branch of service. All rare earth oxides used by the DoD come from China. DoD contractors receive these oxides either through direct importation from China or from Japanese companies that also purchase from China and then channel them to defense contractors in the U.S. Rare earth minerals are processed into usable alloys, metals and powders in either Japan or China and then exported to the U.S. for fabrication by defense industry subcontractors.

One of the major concerns stated in the report is about the production of magnets used within the defense industry. According to the USMMA there is very limited domestic production of rare earth metal magnets along with a small amount of rare earth alloy magnets coming from British sources. The majority of magnets used are produced in China where 97 percent of the world's rare earth mineral ore is mined and refined into usable alloys and then imported to the U.S. These rare earth alloy magnets are very important because they are used in several key defense programs in parts such as missile fin actuators, motors and generators.

Other than high power rare earth magnets, the next most important defense use of rare earths comes in the form of structural materials. When processed and combined with other metals rare earths form metal alloys with very important properties. These alloys are used in the manufacture of jet aircraft engines, modern rocket, and missile motors. Rare earth alloys are used for thermal barrier coating on engine parts that are under extreme heat and pressure. There are no current suitable substitutes for these alloys due to their strength properties and extreme heat resistance.

Historical Case Study

The historical case study entitled "The 1973 Oil Crisis" written by Sarah Horton is a prime example of using a limited natural resource in the act of economic coercion by a group of nations trying to change the National Security Policy of the U.S. Horton begins her study with a brief historical description of the events leading to OPEC's decision to stop oil exports to the U.S. and other western nations. In October 1973, the Middle Eastern members of OPEC embarked on an effort to punish the U.S. and other western nations who supplied weapons and aid to Israel during the 1973 Yom Kippur War. This was led by King Faisal of Saudi Arabia and the Middle Eastern members of OPEC who understood their greatest resource and weapon was their control over global oil exports, specifically those exports to powerful western nations like the U.S.

Middle Eastern oil producing nations like Saudi Arabia and Egypt wanted the U.S. and European nations who supplied aid and weapons to Israel to pressure the Israeli government to remove their armed forces from the Sinai. The Arab countries used the oil embargo as a political tactic to coerce the U.S. to use their influence with Israel. They wanted the U.S. to persuade Israel to withdraw from the occupied Arab territories that Israel seized during the previous three wars Israel fought against their neighbors.

The case study gives several examples of the harsh effects felt by the U.S. as a result of the embargo. In the first few months of the embargo, the price of gasoline more than quadrupled. The price of a barrel of oil skyrocketed, not only from the shortage of supply caused by the embargo, but also from the panic caused by oil investors and oil companies when as many as 25 percent of the gas stations in the U.S. had depleted their supply of gasoline. That year, President Nixon mandated that the DoD create a strategic stockpile of oil in the event that the U.S. might need to conduct military operations in a time of chaos and insure that the embargo of resources would not detour military action. The embargo only lasted one year but had profound effects on the world as a whole as stated in the case study. "One of the long-term effects of the embargo was an economic recession throughout the world. Inflation remained above 10 percent and unemployment was at its record high. The era of economic growth which had been in effect since World War II had now ended."[15]

The oil embargo did have some positive side effects with the U.S. The Department of Energy was created by the Nixon administration to develop a national energy policy to move the U.S. towards energy independence.

Articles

The 7 January 2009 *Associated Press* article, "Europeans Shiver as Russia Cuts Gas Shipments: Major Pipeline through Ukraine Closed over Pricing Dispute," reports on the economic dispute between the government of the Ukraine and the Russian owned gas company Gazprom. The Russian gas company Gazprom stopped all supplies of natural gas that flowed via a pipeline through the country of Ukraine. Gazprom accused the Ukrainian government of diverting gas supplies to storage containers in the country of Ukraine without permission or payment.

---

[15]Horton.

The effects of the shutdown of gas through the Ukrainian pipeline did not affect the Ukraine because it held enough reserves to last the nation for over four months without any outside supply. The main victim of this action was the EU. Eighty percent of all natural gas sold by Russia traveled through pipelines that crossed over the Ukraine.[16]

Chinese Economic Practice Articles

In *Newsweek* Magazine author Robert Samuelson has been writing a series of articles on the economic practices of China. In his 22 December 2007 article titled "Goodbye, Free Trade; Hello, Mercantilism" Samuelson lays out a brief overview of how the world in the 18th century used an economic practice called mercantilism during the time of Imperialism. This economic theory was based on the thought that having a large trade surplus generated wealth in the form of gold or silver coin. This practice declined as the economic theory of free trade showed a more positive overall economic growth for a nation.

Samuelson writes that the American use of mercantilist practices prolonged the Great Depression. After World War II the world's markets took the idea of free trade as their main doctrine. Most nations removed their trade barriers and restrictions and the world's economies grew from the end of World War II until the turn of the century. After the turn of the century several nations began to manipulate markets using old mercantilism practices. In this article Samuelson uses the examples of the undervalued Chinese currency, Russia's natural gas market and Venezuela's oil exports to show how

[16] MSNBC.com, World News, "Europeans Shiver as Russia Cuts Gas Shipments," 7 January 2009, http://www.msnbc.msn.com/id/28515983/ns/world_news-europe/t/europeans-shiver-russia-cuts-gas-shipments/ (accessed 25 May 2012).

nations today are using mercantilism practices in order to benefit from other nations' use of free trade.

In another article Samuelson wrote for *Newsweek* "China First" dated 15 February 2010, he lays out in more detail how China has shifted from the Communist theory of production for self-dependence to production for export. According to the article China's economy has increased tenfold since China reengaged with the U.S. in 1978. The U.S. thought that as China became richer through world trade that it would share the same values as other world nations in the market place. As China's economy grew the view was that these economic forces would weaken the Communist grip on China and it would shift more toward free markets. Political thought was that we may not always agree with China but because of the economic dependencies of the two economies, dispute would be manageable.

With China's economic growth they have begun to shift more towards mercantilist practices such as large trade surplus, labor and resource protections. China undervalues its monetary currency the renminbi, in order to protect and create millions of labor jobs each year. China places import limits and tariffs on all goods coming into China in an effort to make them either too costly for the Chinese people or cost prohibitive for firms to import. While at the same time China is going around the world purchasing or securing raw natural resources and energy so that it can produce and export large amounts of goods to maintain their large trade surplus imbalance with the rest of the world.

Chinese Sourced Articles

On 28 August 2012 China.org.cn, the official information website for the government of China, posted an article titled “Official Defends China’s Rare Earth Regulation.” The article tries to outline part of the Chinese government’s position on the regulation and limits placed on the exportation of rare earth minerals from the borders of China. The Chinese Chief Engineer of the Ministry of Industry (MIIT), Zhu Hongren, is quoted as saying “The disorderly development of the rare earths industry has caused enormous damage to the environment.”[17] The article goes on to state that the current Chinese regulations regarding rare earths mining were developed in order to protect the environment and ensure that effective supplies of rare earth metals are available for future use.

A second article from English.xinhuanet.com an English language Chinese news site dated 25 April 2012 titled “Official Defends China’s Rare Eearth Regulation” provides an almost identical statement from Minister Zhu Hongren. Minister Zhu is also quoted as saying “China is willing to cooperate with foreign companies in recycling rare earth metals and developing substitutes for the metals.”[18]

---

[17]Zhu Hongren, “Official Defends China’s Rare Earth Regulation,” China.org.cn, 28 April 2012, http://www.china.org.cn/wap/2012-04/25/content_25234254.htm (accessed 25 May 2012).

[18]English.news.cn, “Official Defends China’s Rare Earth Regulation,” English.xinhuanet.com, 25 April 2012, http://news.xinhuanet.com/english/china/2012-04/25/c_131550234.htm (accessed 25 May 2012).

WTO

Over the past two years the U.S., EU, and Japan have filed a series of complaints and petitions with the WTO claiming that the Chinese government has failed to act in good faith or within the defined protocols of Article XXII of the "General Agreement on Tariffs and Trade 1994" (GATT 1994) in relation to the handling of rare earths mineral exports. On 13 March 2012 the U.S. filed a request for dialog pursuant to Articles 1 and 4 of the "Understanding on Rules and Procedures Governing the Settlement of Disputes (DSU)" with the government of the People's Republic of China. This meeting produced no resolution on the matter.

The U.S. then filed a request for the establishment of a panel by the WTO to help resolve the issue. The U.S. listed three violations according to "GATT 1994" where the Chinese government had placed restrictions and tariffs on the exportation of several types and forms of rare earths, tungsten and molybdenum. Specification one claims China placed export duties on rare earth minerals being shipped out of Chinese territory. The U.S. feels these tariffs are a form of taxes or charges placed on the exports and is in in violation of Paragraph 11.3 of Part I of the accession protocol of "GATT 1994."

Specification two states that China placed export quotas on the amount of rare earth minerals being exported from Chinese territory. "The U.S. considers that these measures are inconsistent with Article XI:1 of the ,GATT 1994, and China's obligations under provisions of Paragraph 1.2 of part I of the Accession Protocol, which incorporates commitments in Paragraphs 162 and 165 of the Working Party Report."[19]

[19]"China–Measures Related to the Exportation of Rare Earths, Tungsten and Molybdenum," Complaint made by U.S., EU, and Japan against China to the World Trade Organization, WT/DS431/6, 29 June 2012 (12-3462), 2.

Specification three refers to export quota administration and allocation. The U.S. claims that China restricted the trading rights of companies wanting to export rare earth minerals through export licensing without regards for prior export performance or capital requirements. "China administers these export quotas on various forms of rare earths, tungsten and molybdenum in a manner that is not uniform, impartial, or reasonable, such as by the use of criteria in the application and allocation process that lack definition or do not contain sufficient guidelines or standards in how they should be applied."[20]

Writings: Economic Coercion

"Sanctions as Coercive Diplomacy: The U.S. President's Decision to Initiate Economic Sanctions" is an article for the September 2001 edition of *Political Research Quarterly* by A. Cooper Drury of Southern Illinois University. Mr. Drury's article looks at the use of economic sanctions from the perspective of the conditions leading to the employment of economic sanctions instead of other instruments of national power. The author acknowledges the standing viewpoint by most scholars that economic sanctions have not been very effective in the past but rather the context in which sanctions are used should be a better gauge of whether or not they are successful. It is the ever increasing interconnectivity of the world's economic system that will allow the use of economic sanctions to begin to achieve desired goals.

This article was chosen for review not because of the fact that the U.S. is using sanctions as a means to coerce another nation into changing its policies or actions, but due to the fact that the author chose to look at the circumstances that lead to the use of

[20] "China–Measures Related to the Exportation of Rare Earths, Tungsten and Molybdenum," 5.

sanctions and not just the sanctions themselves. The definition of the three main options; diplomacy, economic sanctions and military force, and when to use each while dealing with a country who's actions or policies you wish to change, help one to understand the differences.[21] The escalation of a conflict between two states has many costs associated with it, either through political maneuvering between the two parties or within organizations such as the United Nations or the WTO.[22] When diplomatic pressure fails to resolve the conflict the nations involved tend to resort to more costly measures such as economic sanctions or embargos. Only when the first two actions have failed and your nation's will has been decided, should the third and final action, military action, be taken.[23] Most nations choose to use economic sanctions to their fullest extent because military action is very expensive financially and the cost of life is great.

The author's working definition of economic sanctions is "Economic sanctions are foreign policy tools used by the sender country to pressure the target country to conform to the sender's demands. Sanctions link negative economic demanded by the sender"[24] In certain cases the use of the military is not an option depending on the situation. So sanctions become the only other option when diplomacy does not achieve the desired effects or influences the other party to change whatever policy or actions are

[21]A. Cooper Drury, "Sanctions as Coercive Diplomacy: The U.S. President's Decision to Initiate Economic Sanctions," *Political Research Quarterly* 54, no. 3 (September 2001): 485-508.

[22]Ibid.

[23]Ibid.

[24]Ibid.

desired. Sanctions must have a clear goal or desired end state along with precise targeting in order to achieve their goals.[25]

"Conflict Expectations and the Paradox of Economic Coercion" was written by Daniel W. Drezner at the University of Colorado at Boulder. This writing by Mr. Drezner looks at what the sender nation expects of economic sanctions versus the traditional method of looking at the final results of the economic sanctions. This writing also takes a more real world look at examples of economic sanctions not just against advisories, but also with allies. Drezner defines his theory as conflict expectations model. His model attempts to explain with accuracy the dynamics of economic coercion practices with results as related to the sender nation's expectations versus the final end state result of success or failure.

The conflict expectations model has two defining themes. One theme is the difference between expectations when using economic sanctions against another nation whether they are ally or foe. When using sanctions against an ally the sending nation tends to know the receiving nation better so they are able to tailor the sanctions for success without damaging the allied nation. When sending sanctions against a nation that is not an ally several other factors come into play when determining what your expectations are for results. A nation that is not allied with the sender nation presents more of a challenge for the sender nation especially if the receiving nation has no expectation of normalizing relations between the two nations. When allied nation uses sanctions, there is an expectation of a normalization of relations afterwards. In most cases it is not the aim of hostile nations to have good or even normal relations afterwards which

[25]Drury, 485-508.

leads to a greater level of resistance against conceding to the sender nations will or pressure.

This leads to the second premise within the conflict expectation model, the perceived length of possible conflict. When an ally uses economic sanctions on another allied nation, the target is usually willing to concede more because they hold the view that this is a short-term problem and they should not have to concede further. Adversarial nations are more willing to except higher costs associated with the implimentation of the sanctions due to the belligerent level of the nations. The nation receiving the sanctions will be more inclined to concede less having the impression in their minds that the conflict will not be fully resolved and that in the future the sender nation is going to seek even more concessions.

Economic coercion expectations can be divided into two ideological paradigms, neoliberal and neorealist. When dealing with economic sanctions, realists pay attention to the balance between what is gained and what is conceded in the negotiations process. This focus on the gap stems from the belief that if the sanctioned nation gives up too much in the process that it will become a weakness in future conflicts. The realist position is when a nation gives in to the other's demands without receiving something in return to counter the perceived unbalance. This is seen as a weakness that can be exploited later if future conflicts arise. Neoliberals focus less on the sum of the outcome and more on the parties involved. If the parties are more ideologically aligned then the possibility of a greater conflict from the difference of the concessions is less likely to involve military action.

If the nations are in a state of persistent discord then there are more factors that have to be taken into consideration such as bargaining reputation and local political power of the government. If the gap in bargaining concessions is greater for one nation, then that nation might gain the reputation of being weak. This position allows other nations in the future to become more willing to use economic sanctions quicker with the mindset that the receiving nation will give into the demands. The same premise is applied if the nation has a history of standing tough in the face of a deadlock. This position would make a nation consider the higher cost of trying to achieve their desired outcome. On the converse side, if a nation has a history of conceding in the face of a hardline stance then that too will be used when calculating the cost of executing economic sanctions. If a nation shows a history of not complying easily with the will of another power and showing a propensity for enduring heavy costs in order to inflict even heavier costs on the sender nation, the sender nation must understand this and manage it through conflict expectation.

In summary, the conflict expectation model takes into effect two expectations. First "states will have some concern for relative gains, because concessions made in the present can be used against nation-states in the future. Second, countries are concerned that conceding in the present will damage their reputation in the future."[26] Disputes between adversaries with the expectation of future conflict will need to take into consideration conflict expectation when using economic sanctions.

---

[26]Daniel W. Drezner, "Conflict Expectations and the Paradox of Economic Coercion," *International Studies Quarterly* 42, no. 4 (December 1998): 709-731.

CHAPTER 3

RESEARCH METHODOLOGY

This study will look at an important area of natural resources that are imported to U.S. that until very recently had little to no attention paid to them. The U.S. has been importing rare earth elements for only the last 10 years after domestic production was stopped because rare earths could be purchased cheaper on the global market. The research in this study will look at the use of rare earth minerals from the viewpoint of national security and Department of Defense.

The report will look at the vulnerabilities of the U.S. defense industry in relation to rare earths imports in the possible event of a foreign nation trying to coerce the U.S. by withholding rare earths shipments in a manner similar to the recent dispute between Japan and China. In 2010, China and Japan were locked in a dispute over a set of islands in the South China Sea which both nations claimed as their own sovereign territory. The Japanese government was holding a Chinese fishing boat captain on charges of violating Japanese laws by fishing near the disputed islands. The Chinese government, knowing how important rare earth minerals were to the Japanese economy, withheld shipments to Japan for two months until the Japanese government released the fishing boat captain.

A second area that will be looked at is the possible effects of a political dispute between two foreign nations. In this situation one nation might withhold economic resources from the second nation could have a major secondary effect on the U.S. even though the U.S. is not directly involved in the dispute. An example of this type of scenario would be the 2009 dispute between the government of the Ukraine and the Russian national gas company Gazprom. The Russian government ordered the natural gas pipelines that flowed through the territory of the Ukraine to be shut down over a disagreement on the price that the Ukraine government was paying for natural gas from the pipeline. The Ukrainian government was not the nation affected by the shutdown; it was the EU who received the natural gas on the other end of the pipeline. Russia was able to achieve their desired effect on the Ukrainian government through pressure exerted by the EU.

In order to answer the secondary research question of how these natural resources are strategic, the author will look at the use of rare earth minerals in key U.S. defense programs. A key focus with be placed on the programs that are deemed vital to national defense and therefore are possibly at a higher risk if there were a disruption of the supply system for rare earth elements to the U.S. This research will be qualitative based on the limits and sensitivity of data relating to the amount of each rare earths element used in the manufacturing process of these sensitive systems. The evaluation criteria will be based upon the importance of the defense system or program to national defense since there is a reasonable amount of data to support the criteria from government reports. What are the possible consequences if the U.S. fails to meet its needs for rare earth minerals required in the production of key defense systems? Are there possible alternatives to rare earth minerals that might be utilized in the production process that meet the U.S. strategic needs?

The author will continue to evaluate the importance of each rare earths element in relation to the availability of each rare element on the international commodities market. The report will look at where the world's rare earths mineral reserves are located and discern whether the current supply of rare earth mineral ore properly reflects the real availability of rare earths on the world commodities market. The research will also look at which nations are mining rare earth minerals along with which nations' rare earth minerals can be purchased on the open market in order to chart the world's supply chain and identify potential vulnerabilities.

Attention will also be given to what products are produced from the rare earth mineral ore or manufacturing processes that use rare earth elements to make the products like rare earth magnets and rare earth metal alloys. The U.S. might purchase these items from a nation which imported the rare earths from a different nation which might lead to the U.S. not properly tracking the rare earths requirements within the national defense industry. The author will attempt to identify which nations these products can be purchased from in order to form a correlation between allied nations and possible hostile nations. The goal is to answer the question, would a foreign nation be able to affect the supply of rare earth minerals to the U.S. or to an allied nation enough to coerce the U.S. into submitting to the desired position of the coercing nation?

CHAPTER 4

ANALYSIS

Why are Rare Earths Important to the U.S. Security Policy?

Over the last 30 years since the success of the high tech global positioning system and laser guided bombs in the first Gulf War the DoD has relentlessly pursued and developed even more high tech weapons. The FY 2011 defense budget spends $346.38 million alone on Joint Direct Attack Munitions which is just one of many types of guided aerial dropped munitions. Every service within the DoD has become reliant on the latest high tech weapon or communication system. The U.S. Air Force has placed it's future dominance of the world's air space in high tech programs such as F35 Joint Strike Fighter. The Army's number one procurement program over the next few years is the development and fielding of the Army's Warfighter Information Network-Tactical (WIN-T) system. The Department of the Navy has placed high priority on the integration of their Aegis Radar and Standard Missile 3 program into the national anti-ballistic missile defense strategy.

The U.S. government places so much of the burden of national security on the DoD and their newest and greatest high tech programs that the importance of the manufacturing and supply of the materials needed to maintain this juggernaut has become increasingly important. As the world's market for trade increases and the supply of raw natural resources becomes globally open for competition, the once clear delineation of where a particular resource derived from has become blurred. This process has become even more complicated as new and even more high tech ways of manufacturing and development of new materials for tech applications has combined raw natural elements from many different sources into new complex materials with truly unique properties that cannot be copied by other elements.

A group of these natural elements called rare earth elements have shown to have very unique and special properties when put through the new manufacturing processes. These rare earth minerals are processed and refined into metals, alloys and synthetic materials that are very strong and have special properties. Some create metal alloys or coatings that are able to withstand higher temperatures than any other metals. While still other rare earth metals can be combined to form the most powerful magnets ever produced by man. With these special traits that rare earth metals and alloys bring to the high tech manufacturing world it is easy to see why they have become so important.

Rare earth metals and alloys are currently vital to the security of the U.S. Rare earths are used in almost every strategically vital defense program currently used by the DoD. There are hundreds of defense programs within the U.S. defense industry, but for the purpose of showing how key rare earths are to the current and future security of the U.S., we will look at key defense programs that are linked to the *National Military Strategy* such as Air Sea Battle and Ballistic Missile Defense. The key components of both of these military strategies rely on advance early warning systems combined with global command and control systems which allow global strike weapons the capability of identifying, targeting and destroying hostile targets over the horizon or across the world while placing the minimum number of U.S. servicemen and women in harm's way and protecting the American homeland from hostile aircraft or missile threats.

The major key components of Air Sea Battle are U.S. air power and global strike capabilities provided by the Air Force and Navy in coordination with DoD intelligence, surveillance, and reconnaissance assets both space based and ground systems. These systems are all connected via data links over the DoD space based satellite communications network.

The Air Force has numerous programs as part of their global strike mission such as the Joint Air-to-Ground Missile, also used by the Navy and Marine Corps. Rare earth elements are used in the manufacturing of the guidance fin actuators for missiles. Multiple components of the Air Force's Exoatmospheric Kill Vehicle and the ground based Missile Defense Missile are made from rare earth alloys and metals. Strategically important UAV's like the RQ-4 Global Hawk, MQ-1 Predator and the MQ-9 Reaper have major components like their multi-spectral targeting systems which are made with rare earth elements.[27]

The Air Force would not be able to achieve any of its main core competencies of air superiority, global strike, and air mobility without rare earths. The three major airframes the Air Force currently uses for the air superiority mission; the F15, F16, and the F22 would all be unable to fly without the major components made with rare earths.[28] All Air Force jet engines are made with rare earth alloys and coatings made from rare earths that are able to withstand the super high temperatures required to produce the massive thrust to propel the jets through the skies. All manufactures of aircraft engines for the DoD use an Yttria-Stabilized Zirconia (YSZ) coating on parts that must remain

---

[27]U.S. Material Management Agency (USMMA), *Defense Supply Chain Assessment: Select Systems Employing Rare Earths* (Washington, DC: Government Printing Office, 7 October 2010), 12.

[28]Ibid., 17.

stable at temperatures above 1,200 degrees Celsius.[29] Thermal Barrier Ceramics (TBC) of which YSZ are a part of, provide a thermal insulating effect between the metal alloy and the super-heated exhaust gases being generated in the jet turbine engines. Without these coatings made from rare earth minerals, key components of the jet engines would have a higher failure rate due to thermal fatigue of the metals and alloys used in the jet engines from exposure to the super high temperatures. Current research does not have a suitable replacement yet for the YSZ because it also has a second added advantage over other ceramic based coatings, for not only does YSZ have a high melting point, along with good heat resistance, but it is also stable when in contact with oxidize scale like alumina which grow from the metals during extreme heat.[30] The Air Force future multi-roles fighter, the F35, will also have an engine, the Pratt and Whitney F135, made with coatings using rare earth minerals and rare earth metal alloys. The F35 with also have a generator and actuator motors which controls the flight actuation control system that will be made with Samarium cobalt magnets. The magnets are needed in the hydraulic pump motors to be able to generate the 3,000 to 5,000 pounds per square inch (PSI) needed to support the aircrafts' flight systems.[31] Air superiority fighters are not the only aircraft in the Air Force inventory to be affected. Every aircraft in the Air Force, every bomber and

---

[29]B. Goswami, A. K. Ray, and S. K. Sahay, "Thermal Barrier Coating System for Gas Turbine Application–A Review," National Metallurgical Laboratory (CSIR), Jamshedpur, India, 4 December 2003, topaz.ethz.ch/function/web-het-secured/pdfs/ Goswami-04.pdf (accessed 8 October 2012).

[30]Kang N Lee, "4.4.2 Protective Coatings for Gas Turbines" (NASA Glenn Research Center, Cleveland State University, Cleveland, OH), 2.

[31]"Hydraulics & Pneumatics, The Challenges of Aircraft Hydraulic Design," Penton Media, Inc., 1 July 1998, http://hydraulicspneumatics.com/aerospace/ challenges-aircraft-hydraulic-design (accessed 8 October 2012).

every transport aircraft, has an engine made with rare earth alloys and using rare earths mineral coatings.

All these aircraft also have sensor and communications packages which are heavily manufactured with rare earth magnets and other components. Key sensor systems like; LANTIRN, LITENING, LITENING AT, AN/AAR-56, AN/ALR-94 and other electronic intelligence systems use Yttrium Iron Garnets and Yttrium Gadolinium Garnets.[32] These synthetic materials made from combining rare earth elements with other compounds have very special and unique magnetic properties used to manipulate and control wavelength frequencies. Yttrium Iron Garnets can be manipulated by changing the chemical composition number of rare earth ions to the amount of iron within the material so they are able to achieve tighter frequency responses within the microwave radio band allowing for greater data or signal through put.[33] These sensor systems are key to the Air Force's ability to maintain our advantage over other world air forces. The USAF Advance Airborne Surveillance radar system uses synthetic rare earths materials like Yttrium Iron Garnets for it radar packages.

Rare earths affect almost every missile program in the Air Force today. Neodymium Iron Boron (NdFeb) and Samarium Cobalt (SmCo) magnets are used in the guidance systems of all major missile programs because the combination of rare earths like Neodymium and Samarium with other harder metals form the strongest magnets currently available. Due to the speed and the forces exerted on the guidance fins of

---

[32]USMMA, 5.

[33]Umit Ozgur, Yahya Alivo, and Hadis Morkoc, "Microwave Ferrites, Part 1: Fundamental Properties," Department of Electrical and Computer Engineering, Virginia Commonwealth University, Richmond, VA, 5 January 2009, 24.

modern missiles, only extremely strong magnets in the actuator motors allow it to maneuver well enough to track and engage targets that are also traveling at super high rates of speed. Missile programs like the Advanced Medium Range Air-to-Air Missile (AMRAAM) the backbone in the Air Force's air combat mission use Neodymium based magnets for its fin actuators, the AIM -9X Sidewinder uses rare earths mixture magnets for it's fin actuators, the same for the AIM -54A Phoenix. Magnets with rare earths mixed with elements are also used in BGM-109 Tomahawk Cruise Missiles or the Joint Direct Attack Munitions, the preferred munitions for close ground support rely on magnets and actuators made of rare earths.[34]

The U.S. Army is not exempt from the use of rare earth elements in its key weapons program. The Army's major program of record within the FY 2012-FY2017 budget is the Warfighter Information Network–Tactical (WIN-T) at roughly $6.1 billion. Rare earths synthetic materials like Gadolinium Iron Garnets and Lanthanum Fluoride crystals are used in the antenna systems for the different components of the WIN-T system. One major use is in the wave guide tubes used in the antenna systems for the Joint Nodal Network (JNN) and Satellite Transmission Trailer (STT) which is the backbone for communications within all the Army Brigade Combat Teams (BCTs). All primary command and control systems for the U.S. Army operate over some form of data transmission medium that uses an antenna system with rare earths synthetic material mixtures in it.

One of the core tenents of U.S. military policy has been the ability for early warning and detection of an attack by an enemy nation with ballistic missiles or aircraft.

[34]USMMA, 8.

Since the 1950s the U.S. has developed and continued to refine its ability to detect these threats through the use of advanced ground based radars and space based observation and detection systems. Even today one of our most important defense programs is the anti-ballistic missile defense program. The two major parts to this program are the detection and tracking of missiles launched at the U.S. or one of our allies coupled with the ability to intercept and destroy any target that is projected to hit a target when deemed necessary to defend. Rare earth elements and the synthetic materials made from them play a key role in the system's capability to target, track, and destroy the target missile.

The author will begin with the mission of detection and the systems used to achieve this mission and rare earths used in them. The national ballistic missile defense programs uses two types of surveillance systems to detect a possible ballistic missile launch. Advanced microwave radar systems are used around the world to detect and track a missile launch. These X-band radar systems are stationed both at sea aboard U.S. Navy ships equipped with the Aegis radar platform and the sea-based X-band radar platform currently based out of Hawaii.[35]

X-band radar operates within the electromagnetic spectrum range of microwaves. Microwave frequencies are defined as radio waves that fall between the ranges of 1.6GHz to 30GHz.[36] This range of frequencies includes the military defined radar bands; L, S, C,

---

[35]USMMA, 60.

[36]"HyperPhysics," Physics and Astronomy, Georgia State University, http://hyperphysics.phy-astr.gsu.edu/hbase/ems2.html (accessed 8 October 2012).

X, Ku, K, Ka, Q, U, V, E, W, F, and D.[37] Yttrium Iron Garnets, Yttrium Gadolinium Garnets, Gadolinium Iron Garnets, Neodymium Iron Boron magnets, Samarium Cobalt magnets and Lanthanum Fluoride crystals all made from rare earths are the key materials for the radars cross field amplifiers,[38] electronic sensors, and traveling wave tubes (TWT).[39] The rare earth elements special magnetic properties allow the signal amplifiers to be able to highly tune the radar's signal characteristic.[40] Every radar system used by the DoD uses a frequency within the microwave radio frequency range. It is the use of rare earth elements in the manufacturing of the synthetic materials that allows these systems to be able to provide the highest levels of sensitivity and accuracy when identifying targets over long ranges.

The next defense system to look at is probably the most strategically important of all the systems and affects more than just the DoD. The National Strategic Satellite program is the core of the DoD's command and control, early warning, intelligences, surveillance and reconnaissance systems. Every combatant commander is connected to the National Command Authority to include the President of the U.S. via the Defense

---

[37]"Electromagnetic Frequency Spectrum," Penton Media, Inc., http://electronicdesign.com/article/communications/understanding-solutions-crowded-electromagnetic-frequency-spectrum-73611 (accessed 8 October 2012).

[38]Christian Wolff, "Crossed-Field Amplifier (Amplitron)," Creative Commons Attribution-Share Alike 3.0, http://www.radartutorial.eu/08.transmitters/tx11.en.html (accessed 8 October 2012).

[39]J. R. Pierce, R. G. E. Hutter, and J. C. Slater, "Traveling Wave Tubes (TWTs)," L3 Communications, http://www2.l-3com.com/edd/products_traveling_wave_tube.htm (accessed 8 October 2012).

[40]"Aegis Combat System," Lockheed Martin, http://www.lockheedmartin.com/us/products/aegis.html (accessed 8 October 2012).

Satellite Communications System III (DSCS III).[41] The DSCS III is the backbone communications system for the Global Command and Control System (GCCS), the DoD's early warning sites, and combatant commands down to the tactical forces on the ground around the world.

Rare earth elements are used in multiple parts of the DSCS III systems, 6-channel Super High Frequency (SHF) transponders systems. SHF is another name for the microwave radio frequency used by military satellites. Much like the DoD's radar systems the DSCS III uses Yttrium Iron Garnets, Yttrium Gadolinium Garnets, Gadolinium Iron Garnets, Neodymium Iron Boron magnets, Samarium Cobalt magnets, and Lanthanum Fluoride Crystals in the two wideband multi-beam earth coverage receiver antennas; two transmit multi-beam, gimbaled dish, and two earth coverage antennas.[42] The other important rare earths element used in the DSCS III program is Gadolinium metal, which has the highest neutron capture cross section of all the elements. This makes Gadolinium metal the best choice for use in satellite housings to absorb the high-energy neutrons in space.[43]

Other national satellites programs have the same equipment and the same rare earth elements components as parts in their systems. Programs like Military Strategic Tactical and Relay (MILSTAR) satellites use the SHF and Extremem High Frequency

[41]Department of Joint, Intragency and Multinational Operations (DJIMO), *Space Reference Text*, A541, Space Operations (Ft. Leavenworth, KS: U.S. Army Command and General Staff College, March 2012), 119.

[42]USMMA, 24.

[43]"Aerospace," Molycorp, Inc., http://www.molycorp.com/products/rare-earths-many-uses/aerospace/ (accessed 8 October 2012).

(EHF) bands. The Navigation Signal Timing and Ranging Global Positioning System (NAVSTAR) Global Positioning System also has rare earths used in the antennas. The Wideband Global Satellite System (WGS) uses nine X- band and 10 Ka-band antennas and is fully capable with the DSCS III system.[44] The WGS satellites have one additional and highly specialized use of rare earth elements. The Xenon-ion propulsion system onboard the satellite uses very special rare earths magnets in the propulsion system.[45]

It is crucial to know that some of the most important and vital defense programs are made with rare earth elements. What makes this relevant is that as of 2011 the U.S. mined zero amounts of the rare earths mineral ore used in the production of these key defense systems. One hundred percent of the rare earth minerals used in the end products assembled in these key defense systems was either mined and/or processed in countries other than the U.S.

The U.S. has been in multiple conflicts over the last 60 years, but none with a major world power capable of providing a full-scale high-intensity fight. For decades the U.S. faced off with the Soviet Union. If the U.S. had ever gone to war against the Soviet Union and the conflict was not nuclear, then the costs in conventional weapons would have been enormous. Just like in World War II, the U.S. would have had to replenish equipment fast and at high rates. Under today's persistent conflicts the U.S. has had time to replenish weapons and ammunition stocks without any major complication in supply chains due to the fact that we are fighting third world nations without any major powers as their allies.

---

[44]DJIMO, 123.

[45]USMMA, 27.

As the current conflicts are beginning to wind down, the U.S. has shifted the national security and military focus to the Asian Pacific region of the world. The national policy does not specify China by name as a foe, but anyone who reads it can tell that the military rise of China is the focus and reason for the policy. China's military is large and very capable as it has been modernizing over the last decade.[46] China has nuclear weapons and the missile capability to launch inter-continental missiles. China has spent billions of dollars over the last 10 years developing anti-access weapons, and weapons capable of destroying satellites in orbit.[47] The government of China as of late is pushing to have a greater role in the Asian Pacific area and has been openly countering U.S. influence in the region.

This means that if the U.S. were to get into an open conflict with China there is a high potential for losing a significant amount of aircraft, ships and possibly satellites to enemy action. Since the U.S. currently has no mining capacity in rare earth minerals and imports 100 percent of the rare earth elements processed to use in these key defense programs, one is led to ask if the U.S. would be able to sustain the military with replacement equipment in the face of high losses. The current answer is that it would be extremely hard to meet the defense industry's requirements for rare earth elements in a time of high conflict because the U.S. and all the defense industries which supply these

[46]Bernard Zand, "Stronger Chinese Navy Worries Neighbors and U.S.," Spiegel Online International, 14 September 2012, http://www.spiegel.de/international/world/strengthening-of-chinese-navy-sparks-worries-in-region-and-beyond-a-855622.html (accessed 8 October 2012).

[47]"China's Military Rise," *The Economist*, 7 April 2012, http://www.economist.com/node/21552212 (accessed 8 October 2012).

weapons, currently rely on China for the rare mineral ore they use to make these weapons.[48]

Supply

Who Has Them?

Contrary to their name, rare earth elements are not actually so rare. Rare earths consist of 17 natural occurring elements on the periodic table. Fifteen of these elements; Lanthanum, Terbium Cerium, Neodymium, Promethium, Holmium, Europium, Gadolinium, Praseodymium, Dysprosium, Lutetium, Samarium, Erbium, Thulium, and Yterbium belong to a group called lanthanides and Yttrium and Scandium round out the group of 17.[49] These minerals are found throughout the world in many countries. What makes them so-called rare is the current availability of large minable deposits. There are only a few areas of the world where one could mine rare earths in enough concentration for it to be profitable.

---

[48]Department of Defense (DoD), Under Secretary of Defense for Acquisitions, Technology and Logistics, *Strategic and Critical Materials 2011 Report on Stockpile Requirements* (Washington, DC: Government Printing Office, January 2011), 5.

[49]U.S. Department of the Interior, "Mineral Commodity Summaries 2011," U.S. Geological Survey, minerals.usgs.gov/minerals/pubs/mcs/2011/mcs2011.pdf (accessed 8 October 2012).

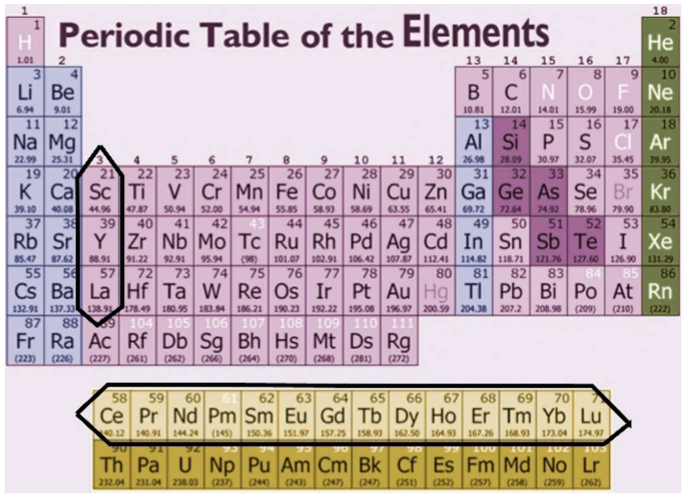

Figure 1. Periodic Table of the Elements

Source: Geology.com, "Periodic Table of the Elements," http://geology.com/articles/rare-earth-elements/ (accessed 25 May 2012).

According to the USGS 2010 report on "Mineral Commodity Summaries" there are currently seven countries around the world that have rare earths deposits that are economically viable for mining. Now there are other countries that have rare earths deposits within their territorial borders but it may not be currently economically advantageous to try to extract the rare earth mineral ore with today's technologies. The seven countries that have minable deposits of rare earth minerals are: China, Commonwealth of Independent States (Russia), U.S., Australia, Brazil, India, and Malaysia.[50]

China has the world's largest proven reserves of mineral ore that produces rare earth elements. According to the USGS, China has 55 million metric tons of rare earth ore reserves. As of 2010, China's Ministry of Industry and Information Technology

[50]Humphries, 14.

reported that China mined 130,000 metric tons of rare earth ore that year which accounted for 97 percent of the world's mined rare earth ore for that year. China is reported to have 50 percent of the world's deposits of rare earth ore both economically minable and none economically viable to mine at current standards.[51]

The second largest known reserves of rare earth mineral ore can be found within the borders of Russia. Russia is reported to have 19 million metric tons of rare earth ore within its borders. Russia accounts for 17 percent of the world's known reserves of rare earth mineral ore deposits. Data on the exact amount of rare earth ore mined each year in Russia has not been publicly published.[52]

The third largest deposits of rare earth mineral ore are found within the U.S. The reserves of rare earth mineral ore in the U.S. are estimated to be at around 13 million metric tons and account for 12 percent of the world's reserves. As of the report in 2010 there were no active mining operations for rare earth mineral ore in the U.S. The last rare earth ore mine to operate within the U.S. was the Mountain Pass mine in the California desert. The Mountain Pass mine closed in 2002 and all mining and production assets were sold to other mining interests.[53]

The remaining world's deposits of economically minable ore totaling approximately 8,578 million metric tons are within the remaining four countries of

[51]Grasso, 11.

[52]Ibid.

[53]Andrew Restuccia, "Troubled Mine Holds Hope for U.S. Rare Earth Industry," *The Washington Independent,* 25 October 2010, http://washingtonindependent.com/ 101462/california-mine-represents-hope-and-peril-for-u-s-rare-earth-industry (accessed 8 October 2012).

Australia, Brazil, India and Malaysia. Of these four countries, Australia has the largest reserves at about 5.4 million metric tons. Currently Australia has no operational rare earth mineral ore mines, but with the recent events showing the importance of rare earth minerals, the government of Australia is pushing to have a mine operational by FY 2013. India produces approximately 2,700 metric tons of rare earth ore each year from its 3.1 million metric tons of reserves. Brazil produces 650 metric tons annually from the countries 48,000 metric tons of reserve ore. The country of Malaysia produces 380 metric tons per year from the 30,000 metric tons of reserve rare earth mineral ore they have within their nation's borders. According to the USGS there are another 44 million metric tons of rare earth minerals deposits around the world, but these deposits are not currently economically viable to mine with today's technologies.[54]

How Are They Produced?

Rare earth minerals are not easy to mine. In most mining operations the ore that is mined not only has rare earth elements in it but other elements such as gold, uranium, phosphates, iron and copper. Rare earth elements are usually produced as a byproduct of the refinement process to extract the other elements such as gold and uranium from the ore. Some of the lighter rare earth elements can be found in greater concentration within the ore, while some of the heavier rare earth elements are found in far lower amounts in the mined ore.

The two most common raw mineral ores that produce rare earth elements are bastnaesite mineral ore and monazite mineral ore. Bastnaesite mineral deposits account

[54]Humphries, 14.

for the largest of the known rare earth elements deposits in the U.S. and China, while the Monazite mineral deposits in Australia, Brazil, and Malaysia account for the majority of the rare earth elements reserves in those countries. These mineral ores are mined and then processed for refinement in order to separate the different elements from the main ore rather it is bastnaesite or monazite. During the refinement process the rare earth elements are separated using a process called leaching. This leaching process is where the rare earth elements are chemically separated from the other elements in the raw ore. This refinement or leaching process is the only known way to separate the valuable minerals such as the rare earths elements for the none valuable elements.

The processing of rare earth elements from the raw ore does have some negative side effects on the environment. The first hazardous effect is the use of chemicals in the leaching process. Large amounts of dangerous chemicals such as cyanide are used to help pull certain elements from the raw ore. These chemicals have to be stored in large ponds at the refinement and processing plants. If the water in these storage ponds were to leak into the aquifer it could poison anyone who uses water from that source. This is a current problem in China near the mines that process the raw ores to extract the rare earth elements. In 2010 China sited this exact reason for placing production and export quotas on rare earth elements in order to try and clean up the environmental effects within China.

The second negative aspect of the leaching and refinement process of raw monazites ore for rare earth elements is the potential for radioactive material. Monazites ore contains thorium and sometimes uranium which are both radioactive. Some 90 percent of the most valuable rare earth elements are found in monazites ore deposits along with trace amounts of radioactive thorium.[55] It was this hazard of radioactive thorium and the declining price of rare earths due to China's flooding the market which led to the closing of the Mountain Pass mine in 2002.

Why Are There So Few Producers?

From the 1960s through the 1980s, the U.S. was the largest and predominant producer of rare earth minerals in the world. At the height of U.S. production, American mines where producing 40,000 metric tons of rare earth minerals per year.[56] Prices for rare earths were steady and did not fluctuate much through the late 1990s. Starting in the late 1980s China began mining rare earths containing ore deposits due to new demand for rare earth elements in new manufacture processes and the new computer age.

---

[55]Humphries, 13.

[56]Brad Plumer, "How to Free the World from China's Rare-earth Stranglehold," *The Washington Post*, http://www.washingtonpost.com/blogs/ezra-klein/post/how-to-free-the-world-from-chinas-rare-earth-chokehold/2011/09/16/gIQA0Zg1XK_blog.html (accessed 8 October 2012).

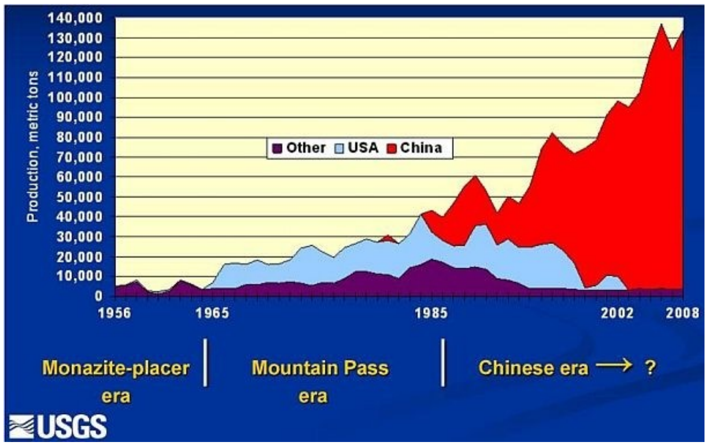

Figure 2. China's Rare-Eath Industry

Source: Pui-Kwan, "China's Rare Earth Industry" (Open File Report 2011-1042, U.S. Geological Survey, Reston, VA, 2011), 3.

As China flooded the rare earth minerals market in the 1990s with more supply than needed by market demand for rare earths, prices began to fall. Chinese mining interests loved the rare earth minerals market for the large profit margins their firms where able to achieve. The Chinese mining firms did not have to follow the stricter environmental and pollution regulations which added extra costs to the U.S. firms. As Chinese firms continued to mine more and more tons of rare earths, the price per ton fell to levels that made it unprofitable for U.S. firms to continue to mine and process rare earths within the U.S. This, coupled with new and tighter environmental laws in the U.S. drove the last rare earths mine in California to close in 2002.[57] Until recently, prices had remained at low levels which prevented other countries from mining rare earths. After the incident between Japan and China in 2010, the world's market price for rare earths spiked shapely due to worries that China might cut off supplies to other nations.

[57]Plumer.

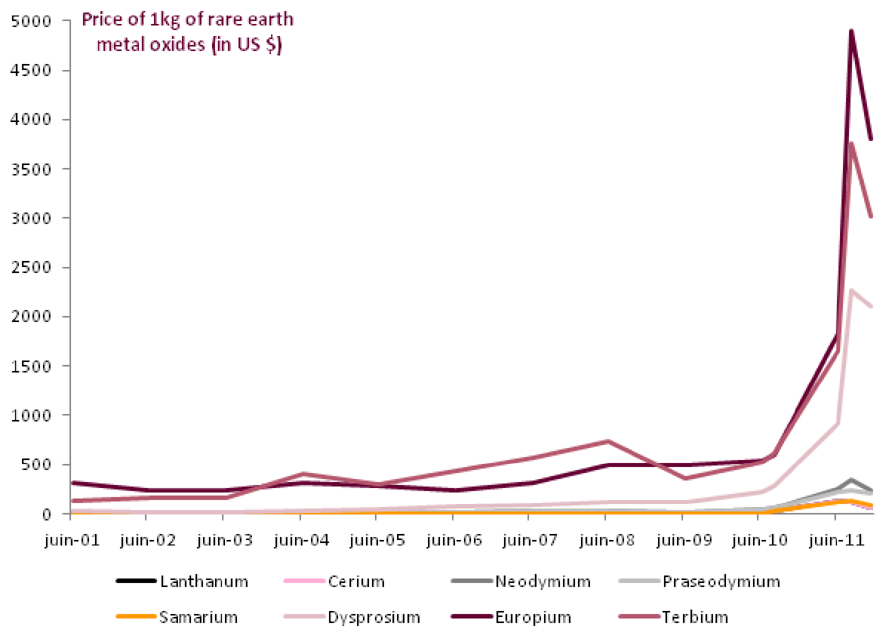

Figure 3. Price of Rare Earth Metal Oxides

Source: energy.sia-partners.com, "Price of Rare Earth Metal Oxides," http://energy.sia-partners.com/2075 (accessed 8 October 2012).

A very limited number of countries mine rare earths today. There are only a few select countries with very relaxed environmental standards: China, India, Brazil, Russia and Malaysia. Minus China, the remaining three countries only produce three percent of the total rare earths mined. As manufacturing and higher tech industries grow in India, Russia and Malaysia the availability of rare earths mined in those countries for export diminishes exponentially. The actual production numbers for the rare earths mining in Russia has not been released but if one were to combine the production of India, Brazil and Malaysia together they would not be able to meet half of the demand for rare earths in the U.S. which was 9,987 metric tons as of 2010.[58]

Where Does the U.S. Get Theirs From?

According to the USGS survey of 2011 the U.S. imported 100 percent of our rare earth elements at a cost of $161 million.[59] That was an increased cost from the previous year reported where the U.S. still imported 100 percent of our needed rare earths but had paid $116 million. In 2009 the U.S. imported 100 percent of the rare earths elements at a total price of $84 million, while in 2008 the U.S. spent $184 million to import 100 percent of the needed rare earth elements.[60]

From 2006 through 2010 the U.S. received 91 percent of imported rare earth elements directly from China. These imports were in the form of rare earth elements processed into rare earth oxides, alloys, metals, rare earth chlorides and some synthetic compounds made with rare earths.[61] Three percent of the rare earths were imported to the U.S. from France. None of the rare earths received from France were mined in France, they too were imported to France from China. French companies imported rare earth

---

[58]U.S. Department of the Interior, "Mineral Commodity Summaries 2011," U.S. Geological Survey, minerals.usgs.gov/minerals/pubs/mcs/2011/mcs2011.pdf (accessed 8 October 2012).

[59]Ibid.

[60]U.S. Department of the Interior, "Mineral Commodity Summaries 2010," U.S. Geological Survey, minerals.usgs.gov/minerals/pubs/mcs/2010/mcs2010.pdf (accessed 25 May 2012).

[61]U.S. Department of the Interior, "Mineral Commodity Summaries 2011."

elements from China then combined the rare earths with phosphors so that American companies can make electric displays used in both military and civilian applications.[62]

Japan provides the next three percent of rare earth imports to the U.S. in the form of rare earth oxides, metals, alloys and powders. Rare earths imported from Japan fall into the same category as the rare earths imported from France. None of the rare earth elements were mined in Japan; they too were imported from China. Japan imports rare earth elements from China then processes the rare earths into oxides, rare earth metals, rare earth alloys and rare earth powders. Some of the processed rare earths mineral products are then manufactured into things like rare earth magnets or chemical catalysts for export to countries like the U.S.[63] The remaining two percent comes from other nations around the world.

---

[62] USMMA, 3.

[63] Ibid.

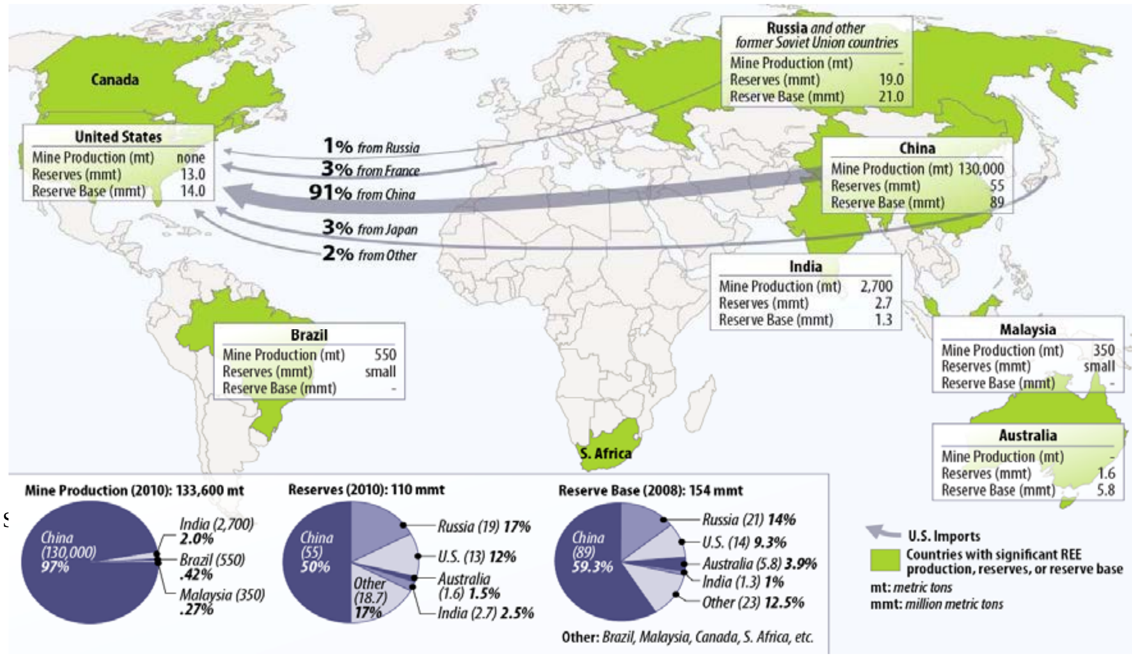

Figure 4. U.S. Rare Earths Imports

Source: Congressional Research Service,"Mineral Commodity Summaries, 2008-2011" (U.S. Geological Survey, 6 September 2011), 15.

Now how did the U.S. allow itself to be in a position where it receives such a vital resource as rare earths from a country like China which is not deemed to be friendly or our ally like China? The answer to this question can be quite problematic. According to current policy it is the job of the Strategic Materials Protection Board (SMPB) within the DoD to determine what materials are deemed critical and vital to national defense. The SMPB was started in 1939 with the "Strategic and Critical Materials Stockpiling Act of 1939." Rare earths had not been placed on the SMPB list of critical materials and had not been placed in National Defense Stockpile.[64]

[64]U.S. Department of the Interior, "Mineral Commodity Summaries 2010."

In 2008, prior to the incident between China and Japan over rare earths exports, the SMPB released their biannual report which defined critical materials as "the criticality of a material is a function of its importance in DoD applications, the extent to which DoD actions are required to shape and sustain the market in the likelihood of a supply disruption."[65] At that time only one rare earths element was named to be strategically vital to national security and that was Beryllium. The report stated:

> High purity beryllium is essential for important defense systems, and it is unique in the function it performs. High purity beryllium possesses unique properties that make it indispensable in many of today's critical U.S. defense systems, including sensors, missiles and satellites, avionics, and nuclear weapons. The Department of Defense dominates the market for high purity beryllium and its active and full involvement is necessary to sustain and shape the strategic direction of the market. There is a significant risk of supply disruption. Without DOD involvement and support, U.S. industry would not be able to provide the material for defense applications. There are no reliable foreign suppliers that could provide high purity beryllium to the Department. Recognizing that high purity beryllium meets all the conditions for being a critical material, the Department should take, and has taken, special action to maintain a domestic supply. The Department has used the authorities of Title III of the Defense Production Act to contract with U.S. firm Brush- Wellman, Inc. to build and operate a new high purity beryllium production plant.[66]

Congress and the House Armed Services Committee did not agree with the report's findings that only the rare earth Beryllium was vital to the DoD. The Committee wrote a follow-on report where it outlined that it felt the SMPB's definition for what was a strategically vital material narrowed and limited the abilities of Congress to add to the list of strategic materials. The committee report also criticized the board's limited abilities to consider broader materials and courses of action to safeguard these resources prior to them becoming potentially damaging to national security. The committee felt that

---

[65]Grasso, 8.

[66]Ibid., 9.

the SMPB had only been reactive in nature to events in the world market and not proactive enough for Congress. Then the House put forward H. R. 2647, the "FY 2010 National Defense Authorization Act." Congress resolved the issue in the "FY 2011 National Defense Authorization Act" (P.L. 111-383, H.R. 6523) by redefining the definition by which the SMPB conducts it review to state "materials essential for military equipment, unique in the function it performs, and for which there are no viable alternatives."[67]

After the Congressional report was added to the "FY 2010 National Defense Authorization Act," several congressmen wrote letters to the Secretary of Defense, Robert Gates. These letters requested that he take action to have the DoD review the DoD supply chain because they worried that a disruption in the global supply chain of rare earths could result in the DoD not meeting budgetary guidelines if prices were to rise. The General Accounting Office examined the DoD supply chain for rare earths and reported that the current supply chain, which was solely dependent upon China, was vulnerable and that this could affect national security if not dealt with properly.[68] The Institute for Defense Analyses (IDA) also provided support to the DoD in its report *From National Defense Stockpile (NDS) to Strategic Materials Security Program (SMSP): Evidence and Analytic Support* dated May 2010 that four more rare earth elements;

---

[67]Grasso, 9.

[68]Ibid., 11.

Europium, Terbium, Neodymium, and Samarium needed to be added to critical materials list.[69]

In 2011 using the new definition of critical materials, the DoD released its *Strategic and Critical Materials 2011 Report on Stockpile Requirements* to Congress. In this report the DoD officially acknowledged that rare earth elements needed to be added to the National Defense Stockpile. The report also "strongly suggests the importance of continued, deeper and broader analyses of the potential U.S. vulnerabilities with regard to rare earths."[70] Potential hazards are also laid out: "numerous potential disruptions that the DoD could have to address in the months and years ahead- incidents such as natural disasters, industrial accidents, strikes by miners, political upheavals in supplying countries, terrorist sabotage aboard or deliberate supply disruptions by major foreign producers."[71] This part of the report was addressing the incident between China and Japan and the ramifications that an incident like that could have on the U.S. defense industry.

In September 2011 Christine Parthemore, a fellow at the Center for a New American Security, testified before Congress that the current rare earth's export market dominated by China could give it leverage over the U.S. and other countries that rely on

---

[69]Institute for Defense Analyses, "From National Defense Stockpile (NDS) to Strategic Materials Security Program (SMSP): Evidence and Analytic Support Volume I," May 2010, www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA527258 (accessed 5 October 2012).

[70]DoD, *Strategic and Critical Materials Operations*, *Report to Congress on Operations Under the Strategic and Critical Materials Stockpiling Act during the Period October 2009 through September 2010*, January 2011, 5.

[71]Ibid., 9.

China for their single source of rare earths. She also goes on to say "today, no minerals are more troubling to the U.S. security and foreign policy than rare earth elements."[72] The testimony further highlights the risks to U.S. security policy that if tensions over rare earths or other minerals are elevated this could cause a nation like China to hinder or block U.S. policy around the world until the mineral dispute is resolved, or withhold mineral exports until a policy matter China deems important is resolved to China's satisfaction.

What has the U.S. done or considered doing to fix or mitigate the risks to the current supply chain for rare earth elements? Congress and the DoD have begun to address the issue of critical and strategically valuable materials but the current research shows that they do not fully understand the totality of the problem. As more and more government reports are being published a multitude of problems are coming to light that no one was previously aware of or were not within the scope of past governmental monitoring systems. In the January 2011 Strategic and Critical Materials Operations Report to Congress titled *Operations under the Strategic and Critical Materials Stockpiling Act during the Period October 2009 through September 2010* written by the Under Secretary of Defense for Acquisition, Technology and Logistics, excerpts from the "National Defense Authorization Acts" from 1996 through 2009 are presented. The excerpts show a pattern of Congress using the National Defense Stockpile fund as a sort of slush fund for other projects. In the "Defense Authorization Act of 1999" the profits from the sale of materials in the National Defense Stockpile were to be transferred over

[72] Christine Parthemore, Center for a New American Security, *Testimony before the House Committee on Foreign Affairs Subcommittee on Asia and the Pacific*, 21 September 2011.

the Federal Hospital Insurance Trust Fund and the Federal Supplementary Medical Insurance Trust Fund in the amount of $92 dollars over a five-year period. The “DoD Appropriation Acts of 2000 and 2001” authorized the transfer of $150 million each year from the National Defense Stockpile transaction fund over to the operation and maintenance accounts of the Army, Navy and Air Force ($50 million each per year).[73]

The “National Defense Authorization Act of 2000” amended the restrictions placed on the total dollar amount of the National Stockpile that could be sold from $612,000,000 to $720,000,000 and gave the President the goal of selling $10 million in FY 2000 and $100 million over the next five years, with all funds going to the general treasury account to be disbursed as seen fit. The “National Defense Authorization Act of 2001” ordered the sale of 30,000 short tons of titanium with the funds being transferred to the American Battle Monuments Commission to fund a World War II memorial.[74] In 2004 and 2005 the Congress delegated the responsibility of the management of the National Defense Stockpile from the President to the Secretary of Defense through the DLA.[75]

In FY 2006 the DLA claimed that 95 percent of the materials in the National Defense Stockpile were in excess of the DoD’s requirements and should be sold. In *House Report 109-89* as part of the “National Defense Authorization Act of 2006” the committee had issues with the DoD’s review of the National Defense Stockpile and

[73]DoD, *Strategic and Critical Materials Operations Report to Congress*, 40.

[74]Ibid., 39.

[75]Ibid., 33.

wanted them to look at what materials the U.S. relied on from foreign sources.[76] The DoD did not submit the report to Congress as requested. It was not until April 2009 that the DoD submitted its report titled *Reconfiguration of the National Defense Stockpile Report to Congress*.[77]

Finally as part of the “2010 National Defense Authorization Act”, Congress made it mandatory that the DoD submit a report on what action the department planned on taking as a result of the findings from the previous report. The Armed Services Committee wanted to know how the DoD wanted to change any statues, regulations or policies in order to insure the future of the program and enable it to better identify future requirements. The *2011 National Defense Requirements Report* identified rare earths as a new material to be examined for addition to the National Defense Stockpile. Neodymium and Yttrium made the reports top 10 shortfalls, while Dysprosium, Europium, Praseodymium, Samarium and Terbium were also listed as shortfalls. The 2011 report also tried for the first time to use more up-to-date data to incorporate macroeconomics principles to better understand the global supplies.[78]

In response to the Congressional mandate to provide a way ahead, the director of the DLA updated his published guidance for FY 2012. In the director’s guidance he addresses three key tasks to be accomplished by the end of FY 2012. The first task listed “develop risk mitigation strategies for the 28 critical material shortages identified in the

---

[76]DoD, *Strategic and Critical Materials Operations Report to Congress*, 33.

[77]Ibid., 2.

[78]DoD, *Reconfiguration of the National Defense Stockpile Report to Congress* (Washington, DC: Government Printing Office, April 2009), 7.

2011 NDS Requirements Report." The second task listed had two parts "completion of all rare earth assessments and coordination milestones" and "develop risk mitigation strategies for the seven critical rare earth materials identified in the rare earths assessment." The third and final task listed in the guidance was "partner with other departments and agencies to address additional strategic materials issues and develop risk mitigation strategies."[79]

The U.S. government has been working on multiple pronged approaches to fixing the problem. In the short-term, H.R. 1540, "The National Defense Authorization Act for FY 2012" would require the DLA to form a reserve inventory of rare earths to support defense requirements. To fix the issue for the long-term there are several legislative actions before Congress. H.R. 1388, "The Rare Earths Supply Chain Technology and Resources Transformation Act of 2011" wants to reestablish domestic rare earths supplies within the DoD. H.R. 618, "The Rare Earths and Critical Materials Revitalization Act of 2011" would provide loan guarantees to domestic production of rare earths in the U.S.[80]

With the U.S. government's efforts to provide loans and reduced regulatory requirements for mining rare earths within the U.S. the private sector has begun an effort to reopen the Mountain Pass mine in California. In phase one of the plan to reopen, the Mountain Pass mine is projected to produce up to 20,000 metric tons of rare earth producing ore by 2013. In phase two of the plan for Mountain Pass mine to reopen,

[79]Defense Logistics Agency (DLA), *2012 Director's Guidance* (Fort Belvoir, VA, April 2012), 6.

[80]Humphries, 25.

planners are projecting to be able to produce 40,000 metric tons per year by 2014. U.S. allies like Japan are investing $2 billion in the Mountain Pass mine in order to develop a fully integrated supply chain that MolyCorp, the owners and operators of the Mountain Pass mine, call “mines to magnetics.” Molycorp has partnered with Japanese companies Daido Steel and Mitsubishi Corporation in order to manufacture rare earth magnets.[81] Molycorp has also managed to purchase rare earths processing plants within China in order to take advantage of the lower domestic price of rare earths before China adds tariffs to the export of rare earths.[82] Other U.S. allies have also been making strategic moves to diversify their supply chains by contracting to receive rare earths from mines in Australia when they open in 2013, and from other nations like Malaysia and India as those nations seek to increase production output from current mining operations.[83]

What Are the Alternatives to Rare Earths?

China has been causing turbulence in the worldwide rare earths market by first withholding shipments of rare earths to Japan in 2010 over a dispute of who has ownership of a group of unoccupied islands, then by placing restrictions quotas on the export of rare earths out of China, but allowing Chinese companies to stockpile reserves

[81]“Mine-to-Magnetics,” Molycorp Inc., http://www.molycorp.com/about-us/mine-to-magnetics/ (accessed 8 October 2012).

[82]Mr. Zhang, “Molycorp Jiangyin,” Molycorp Inc., http://www.molycorp.com/about-us/our-facilities/molycorp-jamr (accessed 8 October 2012).

[83]Indrani Bagchi, “Rare Earths’ Pact: Sino-Japan Spat may Profit India,” http://articles.timesofindia.indiatimes.com/2012-10-02/india/34216853_1_rare-earths-japan-relationship-china-and-japan (accessed 8 October 2012); Shivom Seth, “India Boosts Rare Earth Production,” http://www.mineweb.co.za/mineweb/view/mineweb/en/page72102?oid=158406&sn=Detail&pid=102055 (accessed 8 October 2012).

for domestic use.[84] As of 2011, the U.S. defense industry is experimenting with alternative materials in some key defense programs but has not as of yet been able to find a fully suitable replacement or alternative to rare earth materials. Several other industries like electric motor manufacturers that use rare earths are also researching ways to use less or replace rare earths in their products but are also having design issues because most alternatives do not perform to the same high standards or within the requirements, but researchers are hopeful.[85]

Researchers at several large universities and companies are looking into ways of creating magnets with the same or even better strength than today's current rare earth magnets by either using less rare earth elements in a better manufacturing process, or finding ways to use more abundant rare earths in the manufacturing process.[86] The U.S. Department of Energy's Advanced Research Projects Agency currently has 14 projects under its Rare Earth Alternative Critical Technologies (REACT) program. The program's focus is find alternative materials that can be used in magnets and electric motors in order to bring down costs or to find a more plentiful source of materials to use. The research teams within the REACTs program are taking multiple paths to try and find possible solutions.

---

[84]"China's Stockpiling Rare Earth Minerals Causing Worries," *Manilatimes*, http://www.manilatimes.net/index.php/business/top-business-news/26238-chinas-stockpiling-rare-earth-minerals-causing-worries (accessed 8 October 2012).

[85]Anne-Francoise Pele, "Research Project to Avoid Rare-earth Metals for Electric Motors," http://www.eetimes.com/electronics-news/4375437/Research-project-to-avoid-rare-earth-metals-for-electric-motors (accessed 8 October 2012).

[86]Catherine T. Yang, "While Rare-Earth Trade Dispute Heats Up, Scientists Seek Alternatives," National Geographic Society, http://news.nationalgeographic.com/news/energy/2012/03/120330-china-rare-earth-minerals-energy/ (accessed 8 October 2012).

The larger group of projects is focusing on the material composition of magnets in hopes of finding a way to either completely replace rare earth elements or ways to use less of the more expensive rare earths like Neodymium and replace it with a cheaper rare earth like Cerium. The Ames National Laboratory is looking to combined Cerium with other metals in hopes of creating a magnet that will remain stable at the high temperatures generated in today's electric motors. The rare earth Cerium is cheaper and more plentiful than other rare earths used in magnet production. The laboratory is currently working on a prototype electric motor to demonstrate the new magnets.[87]

Another research project by the Argonne National Laboratory is looking at a way to combine the magnetic properties of soft metal magnets with the benefits of harder metals. If they are successful then the new magnet design will require no rare earth elements in order to meet their planned use in the electric motors in wind generators.[88] Researchers at Dartmouth College are trying to create metal alloys with magnetic properties that exceed current rare earth magnets by combining manganese and aluminum.[89] A different team from Case Western Reserve University is also trying to create new metal alloys for super magnets by using an iron-nitride powder. By using cheaper materials the teams hopes to bring down the price of renewable energy by

---

[87]U.S. Department of Energy, "Ames National Laboratory: Cerium-based Magnets," http://arpa-e.energy.gov/ProgramsProjects/REACT/NovelHighEnergy PermanentMagnetWithoutCritica.aspx (accessed 8 October 2012).

[88]U.S. Department of Energy, "Argonne National Laboratory: Exchange-Spring Magnets," http://arpa-e.energy.gov/ProgramsProjects/REACT/NanocompositeExchange SpringMagnetsforMotoran.aspx (accessed 8 October 2012).

[89]U.S. Department of Energy, "Dartmouth College: Manganese-Aluminum-Based Magnets," http://arpa-e.energy.gov/ProgramsProjects/REACT/Nanocry stallinetMnAIPermanentMagnets.aspx (accessed 8 October 2012).

making the electric motors in wind generators more cost effective.[90] Case Western is not the only team looking at iron-nitride based magnets. The University of Minnesota is looking into how to alter the materials structure to improve its ability to maintain high magnetic properties.[91]

Northeastern University is developing a process to mimic the crystal structures that form from iron and nickel in space. The unique material structure in theory should allow the cheaper metal alloy of iron-nickel to hold the same magnetic properties of the best commercial rare earth magnets at a reduced price.[92] The University of Alabama is trying a similar technique to alter the nanostructure of iron-manganese alloys in hopes of creating a new magnetic material that is superior to rare earth magnets.[93] Pacific Northwest National Laboratory wants to alter the nanostructure of a manganese alloy allowing the softer metal to maintain magnetic properties at temperatures above 200

---

[90]U.S. Department of Energy, "Case Western Reserve University: Iron-Nitride Alloy Magnets," http://arpa-e.energy.gov/ProgramsProjects/REACT/TransformationEnabledNitrideMagnetsAbsentRare.aspx (accessed 8 October 2012).

[91]U.S. Department of Energy, "University of Minnesota: Iron-Nitride-Based Magnets," http://arpa-e.energy.gov/ProgramsProjects/REACT/SynthesisandPhaseStabilizationofBodyCenterT.aspx (accessed 8 October 2012).

[92]U.S. Department of Energy, "Northeastern University: Iron-Nickel-Based SuperMagnets," http://arpa-e.energy.gov/ProgramsProjects/REACT/MultiscaleDevelopmentofL10MaterialsforRareE.aspx (accessed 8 October 2012).

[93]U.S. Department of Energy, "University of Alabama: Rare-Earth-Free Nanostructure Magnets," http://arpa-e.energy.gov/Portals/0/Documents/FundedProjects/REACT%20Slicks/Final_Slick_Univ%20Of%20Alabama.pdf (accessed 8 October 2012).

degrees Celsius. If successful, this technology would reduce the need for expensive cooling systems in both wind turbines and electric motors.[94]

Toyota is working with Tesla Motors, of Palo Alto, California to develop a hybrid vehicle that uses no rare earth metals in the motor.[95] A company called Baldor Electric is currently developing a new electric tractor motor that contains no rare earth materials. The company claims their new electric motor will produce more torque than current electric motors while reducing the total cost of the motor by using no expensive rare earth materials.[96] In coordination with the electric motor industry a group of researchers at the Brookhaven National Laboratory's Advanced Energy Materials Division is attempting to develop new superconducting wire technology that can transport 600 times more electric current that today's standard copper wire. This increased efficiency in the wire structure used in electric motors will allow for the use of smaller or non-rare earth magnets in electric motors. [97]

Research into alternatives to rare earths in microwave communications and radars is ongoing in both the defense industry and private sector. Finding literature and

---

[94]U.S. Department of Energy, "Pacific Northwest National Laboratory: Manganese-Based Magnets, http://arpa-e.energy.gov/ProgramsProjects/REACT/ManganeseBasedPermanentMagnetwith40MGOeat2.aspx (accessed 8 October 2012).

[95]Tatyana Shumsky, "Testing Their Metals," *The Wall Street Journal*, 11 September 2011, http://online.wsj.com/article/SB10001424053111903639404576516012428805034.html (accessed 8 October 2012).

[96]U.S. Department of Energy, "Baldor Electric Company: Rare-Earth-Free Traction Motor," http://arpa-e.energy.gov/Portals/0/Documents/FundedProjects/REACT%20Slicks/Final_Slick_Baldor.pdf (accessed 8 October 2012).

[97]Kay Cordtz, "Is There a Cheaper, Abundant Alternative to Rare Earth?" *Innovation*, April 2012, http://www.innovation-america.org/there-cheap-abundant-alternative-rare-earth (accessed 8 October 2012).

specifications on the research being done within the defense industry is difficult and next to impossible to find in open source format because it is classified and not for public release. The private sector has been working on ways to make components for microwave communication more energy efficient without using rare earths.[98]

Summary

The research in this chapter identified the importance of rare earth minerals within the defense industry of the U.S. and their correlation to national security. An analysis of the world's supply chain for rare earth minerals showed that China has manipulated the worlds market for rare earths, leading to China being the world's sole major supplier of rare earth minerals. Further analysis of the DoD supply chain for rare earth elements showed that all rare earth materials being used within the DoD could be traced back to one source of supply, China. The data also provided a look at the failure of the U.S. government programs designed to identify and mitigate just such risks in the DoD supply chain. A snapshot of the research currently being conducted into alternatives to rare earths shows that the U.S. defense industry will continue to need rare earths products in microwave radio technology in the foreseeable future.

[98]Ulrich L. Rohde, Juergen Schoef, and Ajay Kumar Poddar, "Cost-Effective VCOs Replace Power-Hungry YIGs," miredaktion.sv-www.de/imperia/md/.../417 pdfyigreplacement.pdf (accessed 8 October 2012).

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

From the end of World War II until the beginning of the new millennium, the U.S. had produced enough rare earth elements to both meet the needs of U.S. industry and to export enough rare earth minerals to meet half the world's supply demand. Just before the turn of the century, with little to noone in the U.S. DoD paying attention, this valuable domestically produced strategic resource was allowed to fade away. As China pushed the market prices too low for American companies to remain profitable which led to the end of all domestic production of rare earth minerals. The research has shown it was a short-sighted strategic error by the U.S. government to let the only domestic production of rare earths fold due to market pressures. The failure to understand the importance of having a secure supply of rare earth elements at a time when rare earths were becoming increasingly vital within the defense industry, left the U.S. vulnerable to coercive action if a hostile nation or terrorist organizations took action to disrupt or cut off supplies of rare earths.

The U.S. governmental systems that were designed to track strategic materials such as the "Strategic and Critical Materials Stockpiling Act" first enacted in 1939, failed to fully adapt to the changing global market for raw natural resource. The purpose of the act was "to provide for the acquisition and retention of certain strategic and critical materials and to encourage the conservation and development of sources of such materials within the U.S. and thereby to decrease and to preclude, when possible, a dangerous and costly dependence by the U.S. upon foreign sources for supplies."[99] Multiple agencies within the U.S. government failed to fully understand the new evolving global dynamic between raw natural resources and processed natural resources and how they reach the global market, sometimes through multiple companies spanning more than one nation. This failure to see the larger picture and change the governing laws accordingly allowed the defense industry to purchase processed rare earth products like magnets from cheaper suppliers outside the U.S. without fully understanding the complete supply chain.

U.S. governmental regulations and oversight had changed very little over the decades leading to outdated bureaucratic processes put in place in the 1930s to attempt to monitor an ever growing and complex world market where resources can pass between multiple countries or companies before reaching a vital strategic program or system in the U.S. The six-year gap between the closing of the Mountain Pass rare earths mine in California until members of the House Armed Services Committee identified that the outdated definitions that the SMSP were using to define critical materials had not discovered the DoD's vulnerabilities in correlation to the rare earths minerals market being dominated by China who supplies 97 percent of the entire world's production.

Since 2008 both Congress and the DoD have conducted multiple studies to identify what materials are used in major and vital defense programs. In these studies an emphasis has been placed on charting the entire supply chain and tracking the real source of the natural resources used to produce the components and not just on where the component was made for key defense programs. With this information, Congress and the

[99]DoD, *Strategic and Critical Materials Operations Report To Congress*, 1.

DoD have begun to make changes in the way they identify natural resources as strategic and critical for national defense, the way the DoD supply chain is monitored, and how vital supplies are handled.

Congress has several House resolutions currently pending review at key boards and committees to be brought to the floor for vote. "H.R. 618: Rare Earths and Critical Materials Revitalization Act of 2011" would like to develop a rare earth materials program and amend the "National Materials and Minerals Policy, Research and Development Act of 1980."[100] H.R. 1388: "Rare Earths Supply Chain Technology and Resources Transformation Act of 2011" would reestablish a competitive domestic rare earth minerals production industry and a domestic rare earths processing, refining, purification, and metals production industry.[101]

As production of rare earths are scheduled to resume at the Mountain Pass mine in California in FY 2012, the vulnerability of the U.S. to coercion from China in relation to rare earth minerals has slowly begun to pass as the U.S. becomes more self-reliant for its rare earths needs. By FY 2014 when Mountain Pass in California is at its fully planned production capacity of 40,000 metric tons of ore,[102] major strategic allies like Japan who would otherwise be highly susceptible to China's will within the rare earth's market, will begin to receive a larger portion of their rare earth minerals needs from the U.S. This will

---

[100] *Rare Earths and Critical Materials Revitalization Act of 2011*, H.R.618.IH, 112th Congress.

[101] *RESTART Act*, H.R.1388.IH, 112th Congress.

[102] "Mountain Pass Production," Molycorp Inc, http://www.molycorp.com/about-us/current-future-production/ (accessed 8 October 2012).

allow Japan to no longer be a victim of China's coercive policies in relation to rare earth minerals.

The actions taken over the past four years have been a series of quick patchwork fixes that are now finally leading to some real analysis by the government in order to resolve the deficiencies. The DoD, in concert with Congress, needs a comprehensive overhaul of the current system. The government needs to better understand the evolving world economy in order to protect the vital resources that are being identified in all the current reports being conducted by the Pentagon and Congress. When the current initiatives being undertaken at the DLA are completed, hopefully the gaps in the past analysis will close and this will lead to real solutions.

Recommendations

The first recommendation is that Congress establishes a full-time oversight committee either within Congress or established by law within one of the cabinet secretaries' offices. The purpose of this committee would be to continuously monitor the critical materials that are vital to the overall security of the U.S. This would include but not be limited to critical materials for defense, materials vital to the U.S. economy, key infrastructure and any other area that Congress deems fit to label critical.

This committee would need to be larger and more all-encompassing than the one the DLA is setting up in response to reconfiguring the National Defense Stockpile. During the author's analysis to find which natural resources could be considered strategic, it was also noted that key resources that the DoD considered critical are also labeled as critical to other parts of the U.S. economy or infrastructure. Elements like rare earths are very important to the entire communication network within the U.S. Rare earth elements are also important in the energy sector as catalysts in refining or magnets in power generation.

With so many areas in the U.S. that utilize the same critical resources for so many different purposes, the committee would need to have representation from more than just the DoD in order to ensure that all vital area are given equal weight. The Department of Homeland Security, Department of Commerce, Department of the Interior, and the Department of Energy are just to name a few that need to been represented to make sure their needs are addressed equally. One would also want a few economic experts to maintain the most current economic models and market trends when the committee conducts it evaluations.

Recommendations for Future Research

The newer conflict scenarios that the DoD is starting to implement with the SMSP take into account all the threats that the *Quadrennial Defense Review* projects the nation might face in the future. Threats from hostile nations, terrorist groups, and even non-violent political instability are accounted for, but little attention is paid to multinational super-corporations. As the world's economy grows larger, corporations are becoming so enormous that their revenues can far exceed some countries' total GDP. For example, the top 167 companies on the *Fortune 500* list have annual revenues that are higher[103] than the GDP for 31 of the 37 nations in Africa.[104] This leaves open the possibility for a

[103]Cable News Network, "Global 500," http://money.cnn.com/magazines/fortune/global500/2012/full_list/101_200.html (accessed 8 October 2012).

[104]"Trading Economics," http://www.tradingeconomics.com/gdp-list-by-country?c=africa (accessed 8 October 2012).

corporation to grow powerful enough to exert its will on the smaller nations of the world. Future research should look at the possibility of a corporation taking coercive action against the U.S. through market manipulation. These actions could either raise the price of a material so high that it causes a defense programs to bust budget, or could remove a critical material from the market altogether.

BIBLIOGRAPHY

Books

Baldwin, D. *Economic Statecraft*. Princeton, NJ: Princeton University Press, 1985.

Snyder, G., and P. Deising. *Conflict Amoung Nations*. Princeton, NJ: Priceton University Press, 1977.

Government Documents

Congressional Research Service. “Mineral Commodity Summaries, 2008-2011.” U.S. Geological Survey, 6 September 2011.

Defense Logistics Agency. *2012 Director’s Guidance*. Fort Belvoir, VA, April 2012.

Department of Defense. Under Secretary of Defense for Acquisition, Technology and Logistics. *Strategic and Critical Materials 2011 Report on Stockpile Requirements.* Washington, DC: Government Printing Office, January 2011.

———. Under Secretary of Defense for Acquisition, Technology and Logistics. *Strategic and Critical Materials Operations Report To Congress, Operations under the Strategic and Critical Materials Stockpiling Act during the Period October 2009 through September 2010.* Washington, DC: Government Printing Office, January 2011.

———. *Reconfiguration of the National Defense Stockpile Report to Congress,* Washington, DC: Government Printing Office, April 2009.

Hedrick, James B. “Rare-Earths Industry Overview & Defense Applications.” U.S. Geological Survey. Reston, VA, 18 February 2005.

Kwan, Pui. “China’s Rare Earth Industry.” Open File Report 2011-1042. U.S. Geological Survey. Reston, VA, 2011.

Parthemore, Christine. Center for a New American Security, *Testimony before the House Committee on Foreign Affairs Subcommittee on Asia and the Pacific,* 21 September 2011.

U.S. Congress. House. *Rare Earths and Critical Materials Revitalization Act of 2011*. H.R.618.IH, 112th Congress (2011-2012).

———. House. *RESTART ACT*. H.R.1388.IH, 112th Congress (2011-2012).

U.S. Material Management Agency. *Defense Supply Chain Assessment: Select Systems Employing Rare Earths*. Washington, DC: Government Printing Office, 7 October 2010.

Internet Sources

"Aegis Combat System." Lockheed Martin. http://www.lockheedmartin.com/us/products/aegis.html (accessed 8 October 2012).

"Aerospace." Molycorp, Inc. http://www.molycorp.com/products/rare-earths-many-uses/aerospace/ (accessed 8 October 2012).

Associated Press. "China Halts Rare Earth Exports to Japan Amid Tensions over Territorial Dispute, Traders Say." Fox News, 24 September 2010. http://www.foxnews.com/world/2010/09/24/china-halts-rare-earth-exports-japan-amid-tensions-territorial-dispute-traders/ (accessed 10 May 2012).

Bagchi, Indrani. "Rare Earths' Pact: Sino-Japan Spat may Profit India." http://articles.timesofindia.indiatimes.com/2012-10-02/india/34216853_1_rare-earths-japan-relationship-china-and-japan (accessed 8 October 2012).

"China's Military Rise." *The Economist*, 7 April 2012. http://www.economist.com/node/21552212 (accessed 8 October 2012).

China's Stockpiling Rare Eearth Minerals Causing Worries." *Manilatimes*. http://www.manilatimes.net/index.php/business/top-business-news/26238-chinas-stockpiling-rare-earth-minerals-causing-worries (accessed 8 October 2012).

CNN Wire Staff. "Obama Announces WTO Case Against China Over Rare Earths." CNNNews, 13 March 2012. http://www.cnn.com/2012/03/13/world/asia/china-rare-earths-case/index.html (accessed 16 April 2012).

"Coercion." Dictionary.com. http://dictionary.reference.com/browse/coercion?s=t (accessed 25 May 2012).

Coppel, Emily. "Rare Earth Metals and U.S. National Security." American Security Project, 1 February 2011. http://americansecurityproject.org/reports/2011/not-so-rare-earths-2/ (accessed 25 May 2012).

Cordtz, Kay. "Is There a Cheaper, Abundant Alternative to Rare Earth?" *Innovation*, April 2012. http://www.innovation-america.org/there-cheap-abundant-alternative-rare-earth (accessed 8 October 2012).

"Electromagnetic Frequency Spectrum." http://electronicdesign.com/article/communications/understanding-solutions-crowded-electromagnetic-frequency-spectrum-73611 (accessed 8 October 2012).

English.news.cn. “Official Defends China’s Rare Earth Regulation.” English.xinhuanet.com, 25 April 2012. http://news.xinhuanet.com/ english/china/2012-04/25/c_131550234.htm (accessed 25 May 2012).

“Europeans Shiver as Russia Cuts Gas Shipments.” Msnbc.com, World News, updated 7 January 2009. http://www.msnbc.msn.com/id/28515983/ns/world_news-europe/t/europeans-shiver-russia-cuts-gas-shipments/ (accessed 25 May 2012).

“Global 500.” Cable News Network. http://money.cnn.com/magazines/fortune/ global500/2012/full_list/101_200.html (accessed 8 October 2012).

Goswami, B., A. K. Ray, and S. K. Sahay. “Thermal Barrier Coating System for Gas Turbine Application–A Review.” National Metallurgical Laboratory (CSIR), Jamshedpur, India, 4 December 2003. topaz.ethz.ch/function/web-het-secured/pdfs/Goswami-04.pdf (accessed 8 October 2012).

Grasso, Valerie Bailey. “Rare Earth Elements in the National Defense: Background, Oversight Issues, and Options for Congress.” Congressional Research Service Reports for the People, Report #R41744, 31 March 2011. http://opencrs. com/document/R41744/2011-03-31/ (accessed 25 May 2012).

Hongren, Zhu. “Official Defends China’s Rare Earth Regulation.” China.org.cn, 28 April 2012. http://www.china.org.cn/wap/2012-04/25/content_25234254.htm (accessed 25 May 2012).

Horton, Sarah. “The 1973 Oil Crisis.” Brandi Winck, Aerial Communications. www.envirothonpa.org/documents/The1973OilCrisis.pdf (accessed 25 May 2012).

Humphries, Marc. Specialist in Energy Policy. “Rare Earth Elements: The Global Supply Chain.” Congressional Research Service Report #41347, 8 June 2102. http://opencrs.com/document/R41347/2012-06-08/ (accessed 25 April 2012).

“Hydraulics & Pneumatics, The Challenges of Aircraft Hydraulic Design.” 1 July 1998. http://hydraulicspneumatics.com/aerospace/challenges-aircraft-hydraulic-design (accessed 8 October 2012).

“HyperPhysics.” Physics and Astronomy, Georgia State University. http://hyperphysics. phy-astr.gsu.edu/hbase/ems2.html (accessed 8 October 2012).

Institute for Defense Analyses. “From National Defense Stockpile (NDS) to Strategic Materials Security Program (SMSP): Evidence and Analytic Support Volume I,” May 2010. www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA527258 (accessed 8 October 2012).

“Mine-to-Magnetics.” Molycorp Inc. http://www.molycorp.com/about-us/mine-to-magnetics/ (accessed 8 October 2012).

"Mountain Pass Production." Molycorp Inc. http://www.molycorp.com/about-us/current-future-production/ (accessed 8 October 2012).

Pele, Anne-Francoise. "Research Project to Avoid Rare-earth Metals for Electric Motors." UBM Tech. http://www.eetimes.com/electronics-news/4375437/Research-project-to-avoid-rare-earth-metals-for-electric-motors (accessed 8 October 2012).

"Periodic Table of the Elements." Geology.com. http://geology.com/articles/rare-earth-elements/ (accessed 25 May 2012).

Pierce, J. R., R. G. E. Hutter, and J. C. Slater. "Traveling Wave Tubes (TWTs)." L3 Communications, http://www2.l-3com.com/edd/products_traveling_wave_tube.htm (accessed 8 October 2012).

Plumer, Brad. "How to Free the World from China's Rare-earth Stranglehold." *The Washington Post*. http://www.washingtonpost.com/blogs/ezra-klein/post/how-to-free-the-world-from-chinas-rare-earth-chokehold/2011/09/16/gIQA0Zg1XK_blog.html (accessed 8 October 2012).

"Price of Rare Earth Metal Oxides." energy.sia-partners.com. http://energy.sia-partners.com/2075 (accessed 8 October 2012).

Restuccia, Andrew. "Troubled Mine Holds Hope for U.S. Rare Earth Industry." *The Washington Independent*, 25 October 2010. http://washingtonindependent.com/101462/california-mine-represents-hope-and-peril-for-u-s-rare-earth-industry (accessed 8 October 2012).

Rohde, Ulrich L., Juergen Schoef, and Ajay Kumar Poddar. "Cost-Effective VCOs Replace Power-Hungry YIGs." miredaktion.sv-www.de/imperia/md/.../417pdfyigreplacement.pdf (accessed 8 October 2012).

"Russia Shuts Off Gas to Ukraine." BBC News, Europe, 1 January 2009. http://news.bbc.co.uk/2/hi/europe/7806870.stm (accessed 16 April 2012).

Seth, Shivom. "India Boosts Rare Eearth Production." http://www.mineweb.co.za/mineweb/view/mineweb/en/page72102?oid=158406&sn=Detail&pid=102055 (accessed 8 October 2012).

Sharp, Travis. "The Sacrifice Ahead, The 2012 Defense Budget." Center for a New American Security. http://www.cnas.org/2012defensebudget (accessed 25 May 2012).

Shumsky, Tatyana. "Testing Their Metals." *The Wall Street Journal*, 11 September 2011. http://online.wsj.com/article/SB10001424053111903639404576516012428805034.html (accessed 8 October 2012).

Thomason, James S. “From National Defense Stockpile (NDS) to Strategic Materials Secuirty Program (SMSP): Evidence and Analytic Support Vol I.” Institute for Defense Analyses. www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA527258 (accessed 8 October 2012).

“Trading Economics.” http://www.tradingeconomics.com/gdp-list-by-country?c=africa (accessed 8 October 2012).

U.S. Department of Energy. “Ames National Laboratory: Cerium-based Magnets.” http://arpa-e.energy.gov/ProgramsProjects/REACT/NovelHighEnergyPermanentMagnetWithoutCritica.aspx (accessed 8 October 2012).

———. “Argonne National Laboratory: Exchange-Spring Magnets.” http://arpa-e.energy.gov/ProgramsProjects/REACT/NanocompositeExchangeSpringMagnetsforMotoran.aspx (accessed 8 October 2012).

———. “Baldor Electric Company: Rare-Earth-Free Traction Motor.” http://arpa-e.energy.gov/Portals/0/Documents/FundedProjects/REACT%20Slicks/Final_Slick_Baldor.pdf (accessed 8 October 2012).

———. “Case Western Reserve University: Iron-Nitride Alloy Magnets.” http://arpa-e.energy.gov/ProgramsProjects/REACT/TransformationEnabledNitrideMagnetsAbsentRare.aspx (accessed 8 October 2012).

———. “Dartmouth College: Manganese-Aluminum-Based Magnets.” http://arpa-e.energy.gov/ProgramsProjects/REACT/NanocrystallinetMnAIPermanentMagnets.aspx (accessed 8 October 2012).

———. “Northeastern University: Iron-Nickel-Based SuperMagnets.” http://arpa-e.energy.gov/ProgramsProjects/REACT/MultiscaleDevelopmentofL10MaterialsforRareE.aspx (accessed 8 October 2012).

———. “Pacific Northwest National Laboratory: Manganese-Based Magnets.” http://arpa-e.energy.gov/ProgramsProjects/REACT/ManganeseBasedPermanentMagnetwith40MGOeat2.aspx (accessed 8 October 2012).

———. “University of Alabama: Rare-Earth-Free Nanostructure Magnets.” http://arpa-e.energy.gov/Portals/0/Documents/FundedProjects/REACT%20Slicks/Final_Slick_Univ%20Of%20Alabama.pdf (accessed 8 October 2012).

———. “University of Minnesota: Iron-Nitride-Based Magnets.” http://arpa-e.energy.gov/ProgramsProjects/REACT/SynthesisandPhaseStabilizationofBodyCenterT.aspx (accessed 8 October 2012).

U.S. Department of the Interior. “Mineral Commodity Summaries 2010.” U.S. Geological Survey. minerals.usgs.gov/minerals/pubs/mcs/2010/mcs2010.pdf (accessed 25 May 2012).

———. “Mineral Commodity Summaries 2011.” U.S. Geological Survey. minerals.usgs.gov/minerals/pubs/mcs/2011/mcs2011.pdf (accessed 8 October 2012).

Vafeiadis, Michail. “US, EU, and Japan Challenge China’s Rare Earth Export Restrictions.” *The Christian Science Monitor*. http://www.csmonitor.com/World/Global-News/2012/0313/US-EU-and-Japan-challenge-China-s-rare-earth-export-restrictions/ (accessed 8 October 2012).

Wolff, Christian. “Crossed-Field Amplifier (Amplitron).” Creative Commons Attribution-Share Alike 3.0. http://www.radartutorial.eu/08.transmitters/tx11.en.html (accessed 8 October 2012).

Yang,Catherine T. “While Rare-Earth Trade Dispute Heats Up, Scientists Seek Alternatives.” National Geographic Society. http://news.nationalgeographic.com/news/energy/2012/03/120330-china-rare-earth-minerals-energy/ (accessed 8 October 2012).

Zand, Bernard. “Stronger Chinese Navy Worries Neighbors and U.S.” Spiegel Online International, 14 September 2012. http://www.spiegel.de/international/world/strengthening-of-chinese-navy-sparks-worries-in-region-and-beyond-a-855622.html (accessed 8 October 2012).

Zhang. “Molycorp Jiangyin.” http://www.molycorp.com/about-us/our-facilities/molycorp-jamr (accessed 8 October 2012).

Journals/Periodicals

Drezner, Daniel W. “Conflict Expectations and the Paradox of Economic Coercion.” *International Studies Quarterly* 42, no. 4 (December 1998): 709-731.

Drury, A. Cooper. “Sanctions as Coercive Diplomacy: The U.S. President’s Decision to Initiate Economic Sanctions.” *Political Research Quarterly* 54, no. 3 (September 2001): 485-508.

Morgan, C. “Power, Resolve and Bargaining In International Crises.” *International Interactions* 15 (1990): 279-302.

Papers/Theses/Dissertations

Lee, Kang N. “4.4.2 Protective Coatings for Gas Turbines.” NASA Glenn Research Center, Cleveland State University, Cleveland, OH, 2009.

Ozgur, Umit, Yahya Alivo, and Hadis Morkoc. "Microwave Ferrites, Part 1: Fundamental Properties." Department of Electrical and Computer Engineering, Virgina Commonwealth University, Richmond, VA, 5 January 2009.

Other Sources

"China–Measures Related to the Exportation of Rare Earths, Tungsten and Molybdenum." Complaint made by U.S., EU, and Japan against China to the World Trade Organization, WT/DS431/6, 29 June 2012 (12-3462).

Department of Joint, Intragency and Multinational Operations. A541 Space Operations, *Space Reference Text.* Ft. Leavenworth, KS: U.S. Army Command and General Staff College, March 2012.

INITIAL DISTRIBUTION LIST

Combined Arms Research Library
U.S. Army Command and General Staff College
250 Gibbon Ave.
Fort Leavenworth, KS 66027-2314

Defense Technical Information Center/OCA
825 John J. Kingman Rd., Suite 944
Fort Belvoir, VA 22060-6218

Dr. David A. Anderson
DJIMO
USACGSC
100 Stimson Ave.
Fort Leavenworth, KS 66027-2301

Mr. James A. Cricks
DJIMO
USACGSC
100 Stimson Ave.
Fort Leavenworth, KS 66027-2301

Mr. Timothy J. Brown
DTAC
USACGSC
100 Stimson Ave.
Fort Leavenworth, KS 66027-2301