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United States Government Accountability Office
Washington, DC 20548

April 14, 2010

The Honorable Carl Levin
Chairman
The Honorable John McCain
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Ike Skelton
Chairman
The Honorable Howard P. "Buck" McKeon
Ranking Member
Committee on Armed Services
House of Representatives

Subject: *Rare Earth Materials in the Defense Supply Chain*

This letter formally transmits the enclosed briefing in response to the National Defense Authorization Act for Fiscal Year 2010 (Pub. L. No. 111-84), which required GAO to submit a report on rare earth materials in the defense supply chain to the Committees on Armed Services of the Senate and House of Representatives by April 1, 2010. As required, we provided a copy of this briefing to the committees on April 1, 2010, and subsequently briefed the Senate Armed Services Committee staff on April 5, 2010, and the House Armed Services Committee staff on April 6, 2010.

We are sending copies of this report to the appropriate congressional committees. We are also sending copies to the Secretaries of Defense, Commerce, Energy, and the Interior. This report is also available at no charge on the GAO Web site at http://www.gao.gov. Should you or your staff have any questions concerning this report, please contact me at (202) 512-4841 or martinb@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Key contributors to this report were John Neumann, Assistant Director; James Kim; Erin Carson; Brent Corby; Marie Ahearn; Barbara El Osta; and Morgan Delaney Ramaker.

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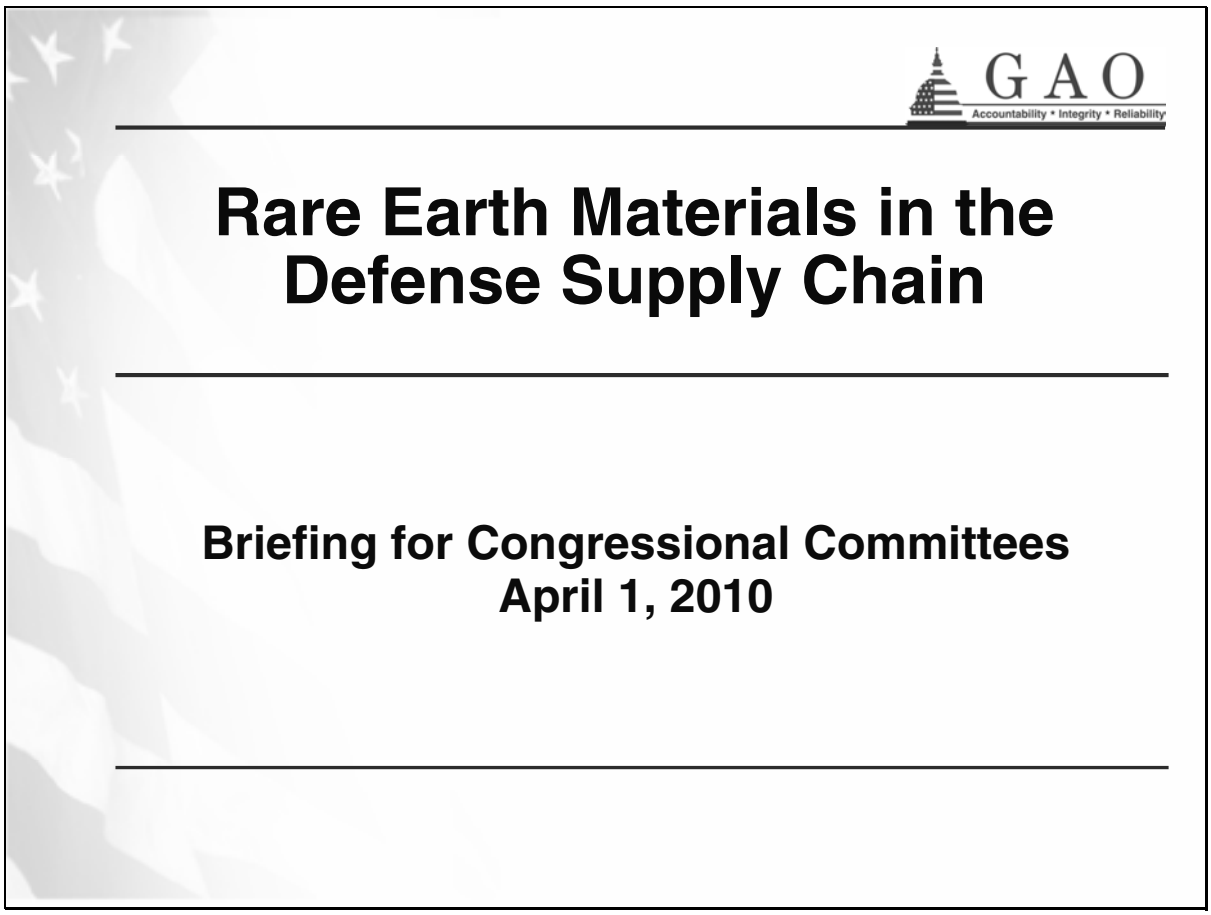
Enclosure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Rare Earth Materials in the Defense Supply Chain
Briefing for Congressional Committees
April 1, 2010

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Introduction

- Rare earth elements are used in many applications for their magnetic and other unique properties. These include the 17 chemical elements beginning with lanthanum, element number 57 in the periodic table, up to and including lutetium, element number 71, as well as yttrium and scandium, which have similar properties.
- Rare earth materials—rare earth ores, oxides, metals, alloys, semifinished rare earth products, and components containing rare earth materials—are used in a variety of commercial and military applications, such as cell phones, computer hard drives, and Department of Defense (DOD) precision-guided munitions. Some of these applications rely on permanent rare earth magnets that have unique properties, such as the ability to withstand demagnetization at very high temperatures.
- Media reports have noted worldwide availability of these materials may be limited to a few overseas sources—primarily China.

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Objectives, Scope, and Methodology

- The National Defense Authorization Act for Fiscal Year 2010, Section 843, directed GAO to submit a report on rare earth materials in the DOD supply chain.[1]
- Objectives:
  - What does existing information show about current sources and projected availability of rare earth materials?
  - Which defense systems have been identified as dependent on rare earth materials?
  - What national security risks has DOD identified due to rare earth material dependencies, and what actions has it taken?

[1]Pub. L. No. 111-84 (2009).

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Objectives, Scope, and Methodology

- To conduct our work, we obtained documentation and interviewed officials to determine the current sources and projected availability of rare earth materials and national security risks DOD has identified and actions DOD has taken.
- We contacted federal agencies and offices, including the following:
  - Department of the Interior,
    - U.S. Geological Survey (USGS);
  - Department of Commerce,
    - Bureau of Industry and Security,
    - International Trade Administration;
  - Department of Energy,
    - Vehicle Technology Program,
    - Wind Technologies Program,
    - Energy Information Administration, and
    - Ames (Iowa) Laboratory;

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Objectives, Scope, and Methodology

- DOD,
  - Office of the Secretary of Defense – Industrial Policy, Office of Technology Transition, Defense Research and Engineering, Science and Technology, and Net Assessment,
  - Defense Logistics Agency, Defense Contract Management Agency, Defense Intelligence Agency, Defense Advanced Research Projects Agency, and Missile Defense Agency,
  - Military departments including: Army Research, Development and Engineering; Army Acquisition, Logistics, and Technology; Army Tank and Automotive Command; Air Force Research Lab Materials and Manufacturing; Naval Surface Warfare Center; Naval Research Laboratory; Navy Research, Development, and Acquisition; and Navy Program Executive Office for Ships.
- We contacted members of industry and academia, including the following:
  - Institute for Defense Analyses, a nonprofit corporation that administers federally funded research and development centers;
  - Academic experts at the University of Delaware and Northeastern University;[2]
  - The National Academies;
  - Rare Earth Industry and Technology Association; and
  - Selected rare earth suppliers from each stage of the supply chain.[3]

[2]We selected a nongeneralizable sample of academics recommended to us through interviews.

[3]We selected a nongeneralizable sample of suppliers representing each processing step from mining to end product based on interviews with government and industry officials.

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Objectives, Scope, and Methodology

- To determine which defense systems are currently dependent on, or projected to become dependent on, rare earth materials, we held discussions with and gathered evidence from government, industry, and academic officials, who identified certain defense systems that use and will continue to use rare earth materials.[4] In addition, we analyzed the supply chains of two specific defense systems to provide illustrative examples of systems that use rare earth materials.
- We used industry reports and data to evaluate the projected worldwide supply and demand of rare earth materials. Uncertainty exists in these estimates due to the assumptions made by different projections. As our findings do not rely on precise estimates of the amount of rare earth material available throughout the world, we found these data to be sufficiently reliable for the purposes of our reporting.

[4]We contacted three of the top five defense contractors, as identified by DOD based on contract award value for fiscal year 2009, as well as selected subcontractors identified by government and industry officials as producers of components containing rare earth materials. These contractors are not intended to be representative of the entire defense supplier base.

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Objectives, Scope, and Methodology

- We conducted this performance audit from January 2010 through April 2010 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

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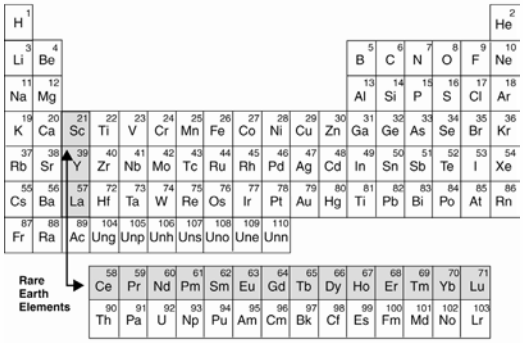
Background: The Rare Earth Elements

- The term “rare earth” denotes the group of 17 chemically similar metallic elements, including lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium, scandium, and yttrium.

Figure 1: Rare Earth Elements in the Periodic Table



Source: GAO graphic based on USGS data.

- Rare earths are often classified into two groups: Heavy Rare Earth (HREE), and Light Rare Earth (LREE), according to their atomic weights and location on the periodic table.

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Background: Rare Earth Materials Are Used in Multiple Commercial Products

- Rare earth elements are used in materials for a number of commercial products, including hybrid cars, wind power turbines, computer hard drives, and cell phones.

Table 1: Examples of Rare Earth Elements Used in Commercial Products

Rare Earth Element Used	Commercial Product
Neodymium, praseodymium, dysprosium, terbium, lanthanum, cerium	Hybrid electric motors and hybrid batteries
Neodymium, praseodymium, terbium, dysprosium	Computer hard drives, mobile phones, and cameras
Promethium	Portable x-ray units
Scandium	Stadium lights
Europium, yttrium, terbium, lanthanum	Energy-efficient light bulbs
Europium, yttrium	Fiber optics
Cerium, lanthanum, neodymium, europium	Glass additives

Source: GAO analysis of government and industry data.

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Background: Rare Earth Material Production Requires a Number of Key Processing Steps

- Rare earth materials require a number of processing stages before they can be used in an application:
  - mining rare earth ore from the mineral deposit;
  - separating the rare earth ore into individual rare earth oxides;
  - refining the rare earth oxides into metals with different purity levels;[5]
  - forming the metals into rare earth alloys; and
  - manufacturing the alloys into components, such as permanent magnets, used in defense and commercial applications.

[5]Metallurgists refer to conversion of oxides into metals as reduction. For the purposes of this briefing, we refer to this step as refining.

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Background: DOD Responsibilities for Managing Supplier Base

- DOD's Office of the Director of Industrial Policy sustains an environment that ensures the industrial base on which DOD depends is reliable, cost-effective, and sufficient to meet DOD requirements. It routinely identifies and works to mitigate short-term supplier-base gaps when these gaps span multiple DOD components.
- The Defense National Stockpile maintains and manages strategic and critical materials.
- DOD military service components (Army, Navy, and Air Force) assess supplier-base issues for existing defense programs or sectors.

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Summary

Objective 1: Current and Projected Availability

- While rare earth ore deposits are geographically diverse, current capabilities to process rare earth metals into finished materials are limited mostly to Chinese sources.
- The United States previously performed all stages of the rare earth material supply chain, but now most rare earth materials processing is performed in China, giving it a dominant position that could affect worldwide supply and prices.
- Based on industry estimates, rebuilding a U.S. rare earth supply chain may take up to 15 years and is dependent on several factors, including securing capital investments in processing infrastructure, developing new technologies, and acquiring patents, which are currently held by international companies.

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Summary

Objective 2: Defense System Dependency

- DOD is in the early stages of assessing its dependency on rare earth materials and is planning to complete its study by the end of September 2010.
- Government and industry officials have identified a wide variety of defense systems and components that are dependent on rare earth materials for functionality and are provided by lower-tier subcontractors in the supply chain.
- Defense systems will likely continue to depend on rare earth materials, based on their life cycles and lack of effective substitutes.
- We found examples of components in defense systems that use Chinese sources for rare earth materials and are provided by lower-tier subcontractors.

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Summary

Objective 3: DOD Identified Risks and Actions Taken

- DOD has not yet identified national security risks or taken departmentwide action to address rare earth material dependency, but expects to consider these issues in its ongoing study expected to be completed by the end of September 2010.
- Some DOD components, other federal agencies, and companies are taking initial steps to limit their reliance on rare earth materials or expand the existing supplier base.

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Objective 1: Rare Earth Ore Deposits Are Geographically Diverse

- Significant rare earth ore reserves exist in China as well as other worldwide locations, including the United States.
- The less-abundant, and more-valuable, heavy rare earth ore deposits are currently found in southern China, but such deposits have also been identified in Australia, Greenland, Canada, and the United States.
- According to industry, rare earth deposits in the United States, Canada, Australia, and South Africa could be mined by 2014.

Table 2: World Mine Reserves and Production

Country	Reserves (t REO)[a]	2009 Mine Production (t REO)
United States	13,000,000	0
Australia	5,400,000	0
Brazil	48,000	650
China	36,000,000	120,000
Commonwealth of Independent States (CIS)[b]	19,000,000	N/A[c]
India	3,100,000	2,700
Malaysia	30,000	380
Other Countries	22,000,000	N/A
World Total (rounded)	**99,000,000**	**124,000**

Source: USGS.

Note: Data are from the Mineral Commodity Summaries 2010.

[a]According to USGS, reserves are the part of the reserve base that could be economically extracted or produced at the time of determination but need not signify that extraction facilities are in place and operative. t REO = metric tons of rare earth oxide.

[b]Regional association made up of former Soviet republics.

[c]Not available.

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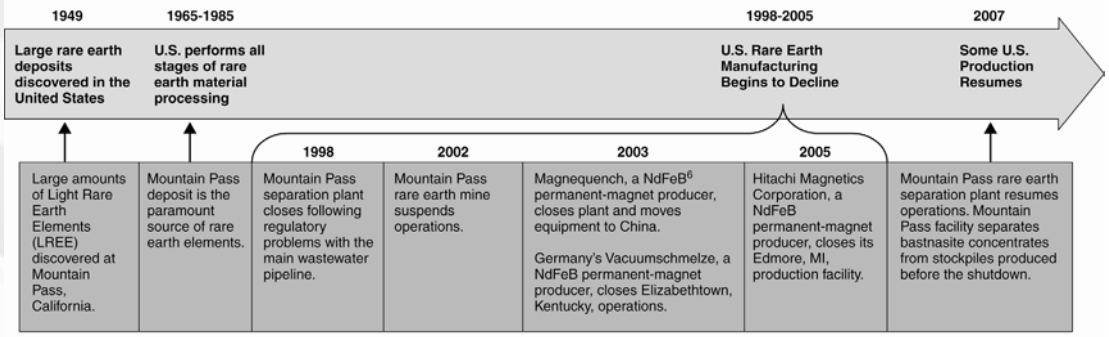
Objective 1: U.S. Industry Previously Performed All Stages of the Supply Chain

- U.S. industry previously performed all stages of the rare earth material supply chain, and the Mountain Pass mine in California produced the majority of the global supply of rare earth materials.

Figure 2: History of the U.S. Rare Earth Industry



Source: GAO analysis of USGS and industry data.

[6]Neodymium iron boron.

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Objective 1: Most Rare Earth Material Processing Occurs in China

- Most rare earth material processing now occurs in China. In 2009, China produced about 97 percent of rare earth oxides.
- Officials of the minerals and rare earth company that owns the Mountain Pass mine expect that by 2012 it will achieve full-scale production of mining and separating cerium, lanthanum, praseodymium, and neodymium oxides.
- The Mountain Pass facility does not currently have the full capability needed to refine the oxides into pure rare earth metals.

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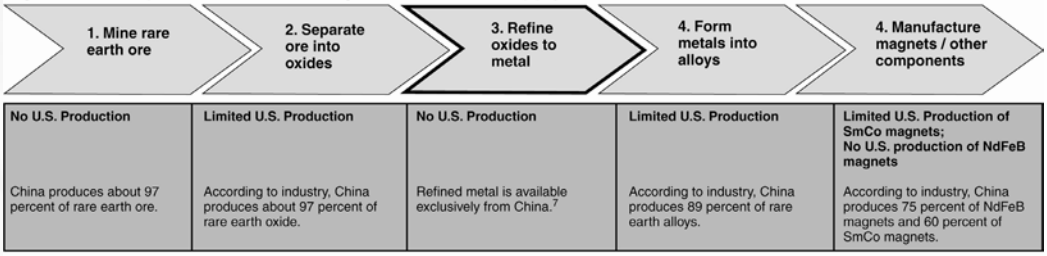
Objective 1: Most Rare Earth Material Processing Occurs in China

Figure 3: Example of Permanent-Magnet Rare Earth Supply Chain



Source: GAO analysis of industry data.

- According to industry data, refined rare earth metals are almost exclusively available from China.
- The United States has the expertise but lacks the manufacturing assets and facilities to refine oxides to metals.
- The United States is not currently producing neodymium iron boron (NeFeB) permanent magnets and has only one samarium cobalt (SmCo) magnet producer.

[7]According to industry, only Chinese companies are producing and selling commercial quantities of rare earth metals. While some Japanese companies produce rare earth metals in a limited capacity, they do not offer these metals as a product but use them to produce alloys and magnets and are dependent on China for rare earth ore. One company in the United Kingdom produces a small quantity of samarium cobalt metal, but also relies on oxides and metals from China.

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Objective 1: China's Market Dominance May Affect Future U.S. Availability of Rare Earth Materials

- According to government and industry data, the future availability of materials from some rare earth elements—including neodymium, dysprosium, and terbium—is largely controlled by Chinese suppliers.
- China's dominant position in the rare earths market gives it market power,[8] which could affect global rare earth supply and prices. In addition:
  - China has adopted domestic production quotas on rare earth materials and decreased its export quotas, which increases prices in the Chinese and world rare earth materials markets.
  - China increased export taxes on all rare earth materials to a range of 15 to 25 percent, which increases the price of inputs for non-Chinese competitors.

[8]Market power is defined as the ability of sellers to exert influence over the price or quantity of a good, service, or commodity exchanged in a market.

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Objective 1: China's Market Dominance May Affect Future U.S. Availability of Rare Earth Materials

- Some government and rare earth industry officials believe that China plans on greater vertical integration of the rare earth materials market in the future, which would increase China's total market power and dominance.
- While China is currently exporting rare earth oxides and metals, some rare earth industry officials believe that in the future China will only export finished rare earth material products with higher value.

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Objective 1: Rebuilding a U.S. Supply Chain Is Dependent on Several Factors

- Although the Mountain Pass mine is the largest non-Chinese rare earth deposit in the world, the mine currently lacks the manufacturing assets and facilities to process the rare earth ore into finished components, such as permanent magnets.
- The Mountain Pass mine also does not have substantial amounts of heavy rare earth elements, such as dysprosium, which provide much of the heat-resistant qualities of permanent magnets used in many industry and defense applications.
- Other U.S. rare earth deposits exist, such as those in Idaho, Montana, Colorado, Missouri, Utah, and Wyoming, but these deposits are still in early exploratory stages of development. Once a company has secured the necessary capital to start a mine, government and industry officials said it can take from 7 to 15 years to bring a property fully online, largely due to the time it takes to comply with multiple state and federal regulations.

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Objective 1: Rebuilding a U.S. Supply Chain Is Dependent on Several Factors

- Other factors may affect the rebuilding of a U.S. supply chain:
  - Capital investment—Industry officials noted that processing companies will need to secure a large amount of capital to begin operations, but investors are concerned about the possibility of the Chinese undercutting U.S. prices and negatively affecting their return on investments.
  - Processing plants—Industry officials said it would take from 2 to 5 years to develop a pilot plant that could refine oxides to metal using new technologies, and companies with existing infrastructure said they would not restart metal production without a consistent source of oxides outside of China.
  - Environmental concerns—Some rare earth minerals are accompanied by radioactive products, such as thorium and radium, which make extraction difficult and costly. In addition, U.S. mines and processing facilities must comply with environmental regulations.

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Objective 1: Rebuilding a U.S. Supply Chain Is Dependent on Several Factors

- New technologies—Some academic experts believe that new processing technologies are needed in order to compete with Chinese producers on price, and academic experts do not believe these technologies will be available on a full production scale for up to 4 years and will require large start-up costs.
- Intellectual property rights—Japanese and other foreign companies currently own key technology patents for manufacturing neodymium iron boron magnets. Some of these patents do not expire until 2014. As a result, companies preparing to enter the neodymium iron boron magnet market in the United States must wait for the patents to expire.
- The development of alternatives to rare earth materials could reduce the demand and dependence on rare earth materials in 10 to 15 years, but these materials might not meet current application requirements.

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Objective 2: DOD Has Begun Assessing Rare Earth Material Dependency

- DOD has begun a review, on its own initiative, assessing its dependency on rare earth materials, that it plans to complete by the end of September 2010. DOD plans to assess its use of these materials as well as vulnerabilities in the supply chain.[9]
- In 2008, DOD Industrial Policy conducted an initial inquiry of DOD departments and agencies to identify strategic and critical materials required for national defense purposes. Although respondents identified a range of systems and components whose production could potentially be delayed due to a lack of availability of rare earth materials, DOD officials stated that this information was not based on a formal study on the use of rare earth materials in these systems.

[9]USGS will conduct a portion of the study that focuses on rare earth element reserves and resources. The Defense Contract Management Agency's Industrial Analysis Center will review trends in pricing of rare earth materials and assess domestic rare earth material production capability.

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Objective 2: Rare Earth Materials Are Widely Used and Lack Substitutes

- According to government, industry, and academic officials, the use of rare earth materials is widespread in defense systems. These include, among others,
  - precision-guided munitions,
  - lasers,
  - communication systems,
  - radar systems,
  - avionics,
  - night vision equipment, and
  - satellites.
- Officials emphasized the significance of the widespread use of commercial-off-the-shelf products in defense systems that include rare earth materials, such as computer hard drives.

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Objective 2: Rare Earth Materials Are Widely Used and Lack Substitutes

- Officials also cited specific components within defense systems that rely on rare earth materials, such as traveling-wave tubes, which amplify radio-frequency signals using rare earth permanent magnets.
- Government and industry officials told us that where rare earth materials are used in defense systems, the materials are responsible for the functionality of the component and would be difficult to replace without losing performance. For example, fin actuators used in precision-guided munitions are specifically designed around the capabilities of neodymium iron boron rare earth magnets.

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Objective 2: Defense Systems Will Continue to Rely on Rare Earth Materials

- Many defense systems will continue to use rare earth materials in the future based on their life cycles and the lack of effective substitutes.
  - For example, the Aegis Spy-1 radar, which is expected to be used for 35 years, has samarium cobalt magnet components that will need to be replaced during the radar's lifetime.
  - According to officials, defense system components that have rare earth materials in them will wear out and need to be replaced.
  - Defense officials said that future generations of some defense system components, such as transmit and receive modules for radars, will continue to depend on rare earth materials. Moreover, in some cases, new systems in development will also rely on components that depend on rare earth materials.

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Objective 2: DOD Defense Systems Use Rare Earth Materials from China

- GAO analysis shows that subcontractors at the lower tiers of the supply chain use rare earth materials sourced from China to produce components used in larger defense systems.
- For example, the DDG-51 Hybrid Electric Drive Ship Program uses permanent-magnet motors using neodymium magnets from China.

Figure 4: Neodymium iron boron (NeFeB) magnets used in DDG-51

Source: GAO analysis of data from government, defense contractors, and rare earth material suppliers.

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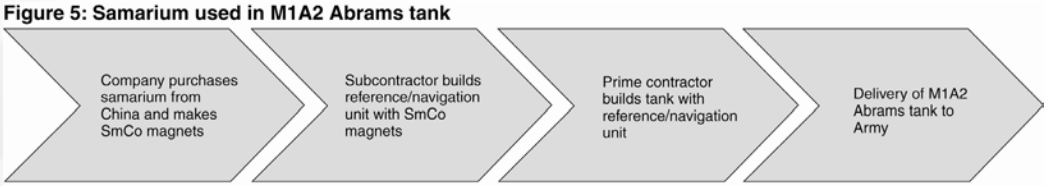
Objective 2: DOD Defense Systems Use Rare Earth Materials from China

- For example, the M1A2 Abrams tank has a reference and navigation system that uses samarium cobalt (SmCo) permanent magnets. The samarium metal used in these magnets comes from China.

Figure 5: Samarium used in M1A2 Abrams tank



Source: GAO analysis of data from government, defense contractors, and rare earth material suppliers.

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Objective 3: DOD in Process of Identifying Departmentwide Security Risks

- DOD has not yet identified departmentwide national security risks due to rare earth material dependencies and is in the process of assessing such risks.
  - While Industrial Policy is aware of rare earth material supply concerns raised by industry and in its initial 2008 inquiry, officials also noted that as part of the office's current study, to be completed by the end of September 2010, they will address vulnerabilities in the supply chain and include recommendations to mitigate any potential risks of supply disruption.
  - DOD has also been involved in efforts to transform the National Defense Stockpile so that materials not produced domestically will be available to support defense needs.
  - A 2009 National Defense Stockpile configuration report identified lanthanum, cerium, europium, and gadolinium as having already caused some kind of weapon system production delay and recommended further study to determine the severity of the delays.[10]

[10]Industrial Policy noted that the stockpile report relied on the same data collected by DOD's 2008 inquiry, which indicated that only one DOD office reported actual production delays due to rare earth material shortages.

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Objective 3: DOD in Process of Identifying Departmentwide Security Risks

- Industrial Policy has existing criteria in the *Defense Acquisition Guidebook* for when program offices should elevate supplier base concerns. These are when an item is produced by a single or sole-source supplier and meets one or more of the following criteria: (1) is used by three or more programs; (2) represents an obsolete, emerging, or enabling technology; (3) requires 12 months or more to manufacture; or (4) has limited surge production capability.
- Generally, Industrial Policy can help DOD offices address a supplier gap or vulnerability when requested. For example, while not related to rare earth materials, Industrial Policy worked with the Army to request a waiver that would allow the Hellfire Missile program to procure a chemical from China that was no longer produced in the United States. This allowed the program to explore a longer-term solution to develop a domestic source for the chemical.

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Objective 3: Some DOD Components Have Taken Steps to Address Rare Earth Risks

- Apart from Industrial Policy's current study, DOD components are also taking steps to address rare earth risks.
  - Air Force's Materials and Manufacturing Directorate examined the availability of rare earth materials and manufacturers of rare earth magnets in a 2003 internal report, which raised concerns about U.S. dependency on Chinese rare earth materials and U.S. industry's lack of intellectual property rights to produce neodymium iron boron magnets. An Air Force industrial base official told us that he was unaware of any actions taken to address the issues raised by the report. However, as we note in this briefing, DOD is in the process of studying these issues.
  - Army's Armament Research Center and the Naval Surface Warfare Center have begun informal efforts to understand the extent of their current and future dependencies on rare earth materials.
  - Also, in 2006, Navy considered funding the Mountain Pass mine and processing facility under a Title III[11] program to secure a domestic source of supply for rare earth materials but ultimately did not award a contract for that purpose as it lost interest in the project.
  - Although DOD has initiated a Title III program for domestic production of traveling-wave tubes, the program does not address domestic sources for the rare earth materials that are required for their production.

[11]Title III of the Defense Production Act of 1950, as amended, provides financial incentives to domestic firms to invest in production capabilities for national defense needs. 50 U.S.C. App. §§ 2091 et seq.

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Objective 3: Other Government Agencies and Industry Also Starting to Address Rare Earth Risks

- Several government agencies have made efforts, in which DOD participated, to address rare earth risks.
  - The Department of Commerce assembled a roundtable to review governmentwide options in addressing potential rare earth shortages.
  - The Office of Science and Technology Policy in the Executive Office of the President recently hosted an interagency meeting to discuss rare earth materials supply and demand and plans ongoing interagency coordination on the issue.
- The Department of Energy reported that it has several research and development efforts to develop non-rare-earth material-dependent motors, reduced rare earth material usage in magnets, and alternatives to rare earth dependent wind generators. In addition, the department recently announced that it will develop a strategic plan for addressing the role of rare earth and other strategic materials in clean energy technologies.
- A major defense contractor is informally surveying its suppliers to understand rare earth materials use in its defense system components and determine alternative solutions to their use.
- Rare earth industry and defense contractors have raised concerns about the Chinese monopoly for rare earth metals.

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Agency Comments

- We provided a draft of this briefing to DOD and the Departments of Commerce, Energy, and the Interior. DOD, Commerce, and Interior provided technical comments, which we incorporated as appropriate. Energy provided no comments.

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