USMMA RARE EARTH MTYH-FACT PAPER – May 2011

The U.S. Magnetic Materials Association ("USMMA") is a trade association dedicated to restoring a competitive, secure, end-to-end rare earth supply-chain to support the domestic manufacturing of rare earth permanent magnets. USMMA is concerned with recent news reports, "think tank" positions, academic reports, U.S. government generalizations and promotional activities by some rare earth industry participants that oversimplify and downplay the seriousness of the rare earth crisis. Therefore, the USMMA is issuing the below "Myth-Fact" paper to clarify key points relevant to the successful reintroduction of a "mine-to-magnets" rare earth supply chain.

Assumption: There is a very limited supply of rare earth elements in the world.

Fact: While rare earths are abundant in the earth's crust, the ability to locate concentrations that are economically viable for extraction and processing is rare.

Names can be misleading. The 17 distinct elements that make up the rare earth grouping are not rare at all. In fact, so-called rare earths are present in "low concentrations throughout the Earth's crust… [and] can be found in almost all massive rock formations,"[1] including in Australia, Brazil, Canada, China, India, the former Soviet Union, the United States, and other locations across the globe.

Unfortunately, the primary problem with mining rare earth elements is one of access. Due to low levels of concentration – sometimes less than ten parts per million by weight – exploration efforts can be daunting. Finding rare earth elements in a significant enough mass to make extraction economically viable is a considerable challenge.

Compounding this economic challenge is the fact that implementation of much-needed environmental regulations has slowed the extraction process and driven up the cost of extraction. Some rare earth mining techniques have caused significant environmental damage; for example, in southeastern China, "miners scrape off the topsoil and shovel golden-flecked clay into dirt pits, using acids to extract the rare earths. The acids ultimately wash into streams and rivers, destroying rice paddies and fish farms and tainting water supplies."[2] Improved environmental

[1] Hurst, Cindy. "China's Rare Earth Elements Industry: What Can the West Learn?" Institute for the Analysis of Global Security (Washington, DC, 2010).

[2] Bradsher, Keith. "Earth-Friendly Elements, Mined Destructively", *New York Times*, December 25, 2009, http://www.nytimes.com/2009/12/26/business/global/26rare.html?ref=global.

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standards, in China and elsewhere, are absolutely necessary but unfortunately have resulted – and will continue to result – in decreased relative supply of these elements.

Assumption: Recent actions by China make them an unreliable supplier of rare earth materials on the global marketplace.

Fact: China has dramatically reduced exports, decreased production, increased taxes on rare earth product, and allegedly embargoed trading partners.

This assumption is unfortunately accurate. China produces more than 95 percent of all rare earth oxides for world consumption. However, the ability – and willingness – of China to export rare earth oxides and metals is eroding due to growing domestic (Chinese) demand, enforcement of environmental laws and regulations, and a mandate to consolidate the industry by decreasing the number of mining permits. As a result, China has imposed several restrictions in the last year, causing significant market disruptions. For example, in July 2010, China decreased their export quota allocations on rare earth oxides and metals by over 70 percent. The market impact was immediate and alarming: these additional restrictions from the world's largest producer of rare earth materials caused a rapid escalation in the price of materials, in increasing prices between three to eight times and causing supply shortages of some materials. In September 2010, China restricted export of all rare earth oxide and metal to Japan over a diplomatic incident and, in October 2010, imposed similar restrictions on exports to the United States and Europe.

Equally troubling is that many Chinese suppliers to U.S. corporations became reluctant to quote pricing and availability to consumers as they anticipated further price increases. Uncertainty in cost and availability highlight a critical vulnerability in the supply chain, as noted in the 2010 GAO report on this topic. The prices of rare earths in 2011 have become progressively higher with increases ranging from 5 to over 20 times their pre-July 2010 levels.

Assumption: Extracting rare earth elements is simple, and U.S.-based companies can quickly develop this capability.

Myth: Extraction is only a small component of the supply-chain. Concentration and separation to individual oxides can cost upwards of $500 million per location and up to 10 years for mine development and permitting.

Processing rare earth elements is much more complicated and costly than processing other ores, such as gold. Miners extract ore that contains rare earths as well as many other minerals. Processors then crush the ore into gravel-sized pieces that can be fed into a grinding mill, which transforms the gravel into a fine sand or silt. The silt then runs through a floatation process, in which processors add an agent to the silt and cause air bubbles to rise through the tank; the bubbles "catch" the rare earth minerals, bringing them to the surface as a froth that can be separated out. The next step involves the addition of acid and various solvents (each rare earth element has its own extraction steps and chemical processes) to separate the rare earth elements into distinct oxides, which can be dried, stored, and shipping for further processing.[3] This process also produces waste water sometimes containing potentially harmful materials, including radioactive thorium, radium, and uranium, which require careful recycling or disposal.

The next steps are to reduce – or refine – the rare earth oxides into metals with different purity levels, form the metals into rare earth alloys, and finally manufacture the alloys into components, such as permanent magnets, for use in defense and commercial applications.[4]

Clearly, successfully processing rare earth elements requires considerable know-how, operational experience, and manufacturing assets and facilities. Currently, there is limited rare earth production in the United States, which remains nearly entirely dependent on overseas refineries for elemental and alloy processing. Generally speaking, most processing occurs in China; Japanese firms produce metals, metal alloys, and magnets, and Germany can produce alloys and magnets. According to a 2009 Government Accountability Office (GAO) briefing to Congress, "based on industry efforts, rebuilding a U.S. rare earth supply chain may take up to 15 years and is dependent on several factors, including security capital investments in processing infrastructure, developing new technologies, and acquiring patents, which are currently held by international companies."[5]

Even foregoing an end-to-end processing capability would require years of investment. A rare earth mine in Mountain Pass, California, is the largest non-Chinese deposit in the world, but it does not have substantial amounts of heavy rare earths (such as dysprosium) for heat-resistant permanent magnets in commercial and defense applications. This facility is currently in the process of a multiyear upgrade for assets and facilities to process rare earth ore into oxide. The aforementioned GAO briefing noted that "according to industry, rare earth deposits in the United States, Canada, Australia, and South Africa could be mined by 2014."[6] On the other end of the supply chain, industry estimates that creating a magnet-producing facility for sintered neodymium iron boron permanent magnets, which play a critical role in several critical defense applications, would also take a minimum of 2 years.

Assumption: Global demand will continue to increase and will outstrip projected supply of key rare earths.

[3] Hurst, Cindy.
[4] Martin, Belva. "Rare Earth Materials in the Defense Supply Chain" briefing to Congress. Government Accountability Office (Washington, DC, April 14, 2010).
[5] Ibid.
[6] Ibid.

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Fact: The world has an increasing appetite for products that rely on rare earths, including green technologies such as: hybrid cars, wind turbines, and compact fluorescent lights; digitized and miniaturized electronic consumer goods such as flat screen televisions, mobile phones, and disc drives; and defense technologies such as munitions, missiles, radar surveillance, and avionics.

Anticipating future shortfalls in critical rare earth elements and materials, many commercial enterprises – especially in the automobile and high-technology industries – have locked suppliers into long-term agreements, an action that has encouraged existing and potential rare earth suppliers to establish or re-open mines and facilities to increase supply in the next 3-5 years.

That said, experts generally agree that certain individual elements, particularly neodymium, dysprosium, europium, terbium, and yttrium, will remain in short supply.[7] As the largest user of dysprosium enhanced neodymium iron boron permanent magnets, the automobile industry – alongside wind turbine manufacturers, makers of defense applications, and others – will face demand growth that is between nine to 15 percent for these scarce rare earth materials. Compounding this situation are the facts that at current rates of production, China has only 5-25 years of dysprosium production remaining[8] and that China may well become a net importer of rare earths in the next 5 to 10 years as more and more Chinese technology uses rare earths. This squeeze on supply will undoubtedly impact U.S. technology and national security sectors.

Industry players can respond to raw material scarcity in a variety of ways: long-term or special supply agreement; stockpile; substitution; or resource efficiency. Businesses are generally adopting a combination of these elements into their business strategies. For example, an element of Toyota is reportedly "securing supplies of lithium used in the batteries for electric vehicles through a partnership with the Australian-listed company Orocobre. The deal will see Orocobre develop resources of lithium-potash in Argentina. The automotive manufacturer is reportedly also developing electric motors that are no longer dependent on [rare earth elements]. And, as a Japanese company, Toyota would also have access to its government's stockpile of strategically important metals."[9]

Like Japan, the United States has a critical material stockpile. However, despite the projected shortfalls in rare earth elements that are essential to defense applications, this strategic reserve does not currently include those elements. In particular, demand will outstrip supply of dysprosium and neodymium, used in magnets that make direct precision-guided munitions (e.g., Joint Direct Attack Munitions, Joint Air to Ground Missiles, Joint Common Missiles), enable stealth technology in helicopters, and withstand vibration, impact, and G-forces in aircraft, tanks, missile systems, and command and control centers. Moreover, Japanese company Hitachi –

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[7] Seaman, John. "Rare Earths and Clean Energy: Analyzing China's Upper Hand." Institut Français des relations Internationales (Brussels, Belgium, September 2010).

c[88] Lifton, Jack. Technology Metals Research, LLC.

[9] Stuff, Paul. "Rarer still? Supply risks of rare earth elements." www.environmentalistonline.com/article/2011-03-17/rarer-still-supply-risks-of-rare-earth-elements (March 17, 2011).

which holds the intellectual property rights – will not provide quotes for "military specification" magnets. Thus, U.S. companies produce critical defense weapons and components by buying magnets from licensed Chinese producers.

The U.S. Government can address this untenable dependency on Chinese sources for critical military applications through establishment of a neodymium iron boron stockpile, as called for in H.R. 1388, the Rare Earths Supply-Chain Technology and Resources Transformation Act of 2011 (or RESTART Act), as introduced by Representative Mike Coffman (CO-6) in April 2011. This legislation calls for a limited, value-added inventory of neodymium iron boron magnet alloy (no more than 200 metric tons) and dysprosium iron alloy (no more than 50 metric tons) within the Defense Logistics Agency Strategic Materials (DLA-SM) stockpile. This inventory would be available, as necessary, to companies that make magnets for defense applications without impact on market prices.

In addition, the RESTART Act would encourage a domestic U.S. manufacturing capability for neodymium iron boron magnets by allowing the Department of Defense to enter into long-term supply contracts for the delivery of necessary grades of domestic neodymium iron boron magnets to meet the defense demand. In this way, the U.S. military would not be dependent on Chinese sources for magnets that are critical to functionality of key defense systems.

Assumption: Even holding China's reliability aside, the industrial base on which the U.S. Defense Department depends is reliable, cost-effective, and sufficient to meet defense requirements in the near- and long- terms.

Myth: The United States currently produces limited rare earth oxides, no rare earth metals, limited rare earth alloys, has one vertically integrated producer of samarium cobalt magnets and no producers of neodymium iron boron magnets. Producers from ally nations are 100 percent dependent on Chinese sources for heavy rare earth materials and largely dependent on China for rare earth metals and alloys.

Certain Defense Department officials have repeatedly offered this mistaken assumption, both to Congress and to industry. Those officials have made no apparent attempt to quantify aggregate defense demand to support this assumption, and statements from industry experts, such as Dudley Kingsnorth, raise critical issues for discussion. Kingsnorth has stated that of total global rare earth demand, demand for metal alloys and magnets is 18 and 21 percent, respectively. Thus, of the 125,000 global oxide demand, 47,500 tons (39 percent) are used for metal and alloy, materials not produced in the United States or produced in tiny amounts. U.S. demand for metal alloys and magnets is 1,000 tons and 500 tons, respectively. Thus, DOD's demand (roughly 8 percent of U.S. demand) is 80 tons of alloy and 40 tons of magnets. U.S. companies are producing nowhere near that amount today.

More disturbingly, in 2015, U.S. demand will be 2,000 tons of metal alloy and 3,000 tons of magnets; DOD's demand (at 8 percent) will thus be 160 tons of alloy and 240 tons of magnets. These amounts are far beyond domestic capability.

To address demand for rare earth materials, the United States needs robust activity in several key areas to support a "manufacturing first" approach, one that supports the mining of rare earth ores domestically but also promotes U.S. capabilities on the manufacturing end of the supply chain. Such an approach would include:

- **Stockpiling value-added materials to support Department of Defense requirements:** The U.S. Government should target the most critical of the 17 distinct rare earth elements, as well as those that are most economically viable in the United States, and use the relevant authorities to launch a rare earth stockpile program within the Defense Logistics Agency – Strategic Materials organization (formerly the Defense National Stockpile Center) that holds an inventory of value-added rare earth materials, such as alloy and magnet block, that could be quickly processed to meet national security needs in the event of an emergency. This program would allow the purchase of existing rare earth supplies on the open market to close a supply chain gap, mitigate national security risk, and create a market to support future production of domestic rare earth mining, refining, processing, and alloying operations. By procuring available rare earth oxide and creating an inventory of value-added materials, domestic capability could be reinvigorated. Also, through this program, the U.S. Government can focus its scarce resources on urgent national security requirements (e.g., heavy versus light rare earths) as a "prudent investment";[10,11]

- **Emphasis on production:** In focusing on defense critical components, U.S. Government officials must mitigate manufacturing – and thus, availability – gaps for necessary materials. For example, the GAO report identified a glaring U.S. vulnerability resulting from our reliance of neodymium iron boron magnets ("neo magnets") from unreliable foreign sources. The Department of Defense should use the Defense Production Act, which exists to address and overcome situations exactly like this one, and the Strategic and Critical Materials Stock Piling Act (50 U.S.C. 98) to restart a reliable, domestic neo magnet manufacturing capability to fix our most pressing rare earth vulnerability. Such a step would help domestic sources process raw materials, invest in value added capability, and create customers for the early stages of the supply chain rather than simply building a raw material capacity without adding value to the U.S. manufacturing base.

[10] Humphries, Marc. "CRS Report: Rare Earth Elements: The Global Supply Chain". Congressional Research Service (Washington, DC).

[11] Cindy Hurst noted in the aforementioned thoughtful paper on lessons learned from China's rare earth elements industry that "building a strategic stockpile of critical rare earth elements capable of sustaining the country for 20 years or more would greatly increase security of supply. Perhaps this is the most important thing the U.S. can do in the near future."

Assumption: Rare earths will not be critical to defense applications over time, and by exploiting market dynamics that raise prices and squeeze supply, China's actions will encourage governments and industry to find substitutes for these materials.

Myth: Many defense applications remain in inventory for decades and cannot be replaced.

A range of defense applications are completely dependent on rare earth materials for their functionality, according to both government and industry officials:

- Precision-guided munitions (e.g., Joint Direct Attack Munitions, Joint Air to Ground Missiles, Joint Common Missiles) use samarium-cobalt or neodymium iron boron permanent magnets to control the fins and thus guide the drop direction of these "smart bombs";
- Neodymium iron boron magnets create white noise to cancel or hide rotor noise, thus enabling stealth technology in helicopters. They are also essential to the DDG-51 Hybrid Electric Drive Ship Program, as well as to aircraft, tanks, missile systems, and command and control centers
- Tanks and other vehicles use rare-earth lasers for range finding, and the main U.S. system for detecting underwater mines uses a rare-earth laser system;
- Military communications satellites use traveling wave tubes and klystrons that rely on rare earth magnets; and
- Military aircraft use samarium-cobalt magnets to help generate electricity for electrical systems, and sections of aircraft engines use yttria-stabilized zirconia, a high-temperature resistant ceramic coating, as a thermal barrier in the "hot" sections of jet engines. In addition, small high-powered rare earth magnet actuators are employed in moving the flight control surfaces of aircraft, including flaps and rudders. Radars and electronic warfare systems rely on rare-earth magnets (often samarium-cobalt) for traveling wave tube amplifiers to amplify power and distribute it.

The use of rare earth materials in defense applications is not new and the difficulty in accessing such products have been well-known. Years of research into substitutes have produced no viable alternatives, and by all accounts, U.S. national security will continue to rely on rare earth metals, alloys, and magnets in the foreseeable future as the U.S. military continues to deploy and use these critical weapon systems.

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Assumption: A solution to the rare earth crisis is to reuse and recycle rare earth materials.

Partial-Myth: While necessary research and development is underway in this field, no large-scale reuse or recycling programs are ongoing.

The recent skyrocketing of rare earth prices has encouraged several large-scale consumers of rare earth materials to examine new ways to reduce their expenditures and diversify their supply sources away from China. One approach is to invest more heavily in rare earth metal recovery and recycling.

According to media reports, most companies are keeping technologies under wraps, but since July 2010, several key players have announced plans to recycle materials. For example, in October, “Japan’s Shin-Etsu Chemical announced plans to extract rare earths from discarded air conditioners and recycle them in magnets, starting [in 2011]. Reuters reports that Shin-Etsu is negotiating with a number of electronic appliance retailers to build a recovery system and the company will be the first in Japan to collect and recycle rare earth metals from appliances.”[12] In December, Hitachi stated it is calculating costs and recovery ratio in the hopes of recycling rare earth magnets, beginning in 2013, from hard disk drive motors, air conditions, and other compressors; Hitachi would use a new “dry process” that uses an extraction material with a high affinity for rare earths instead of acids and chemicals that result in liquid waste. In May, Japanese chemical maker Showa Denko KK opened a plant in Vietnam to recycle dysprosium and didymium metal. Additionally, Bloomberg reports that Mitsubishi Materials Corp., which has recycling ventures with Panasonic Corp. and Sharp Corp., started researching the cost of extracting neodymium and dysprosium from washing machines and air conditioners.

Japan is truly leading the way in these efforts, and in seeing the possible cost savings – and certainly the benefits in diversifying supply away from China – U.S. companies may be interested in following suit.

[12] “New Push to Recycle Rare Earth Minerals”. March 14, 2011. (http://blog.cleantechies.com/2011/03/14/new-push-to-recycle-rare-earth-minerals/)