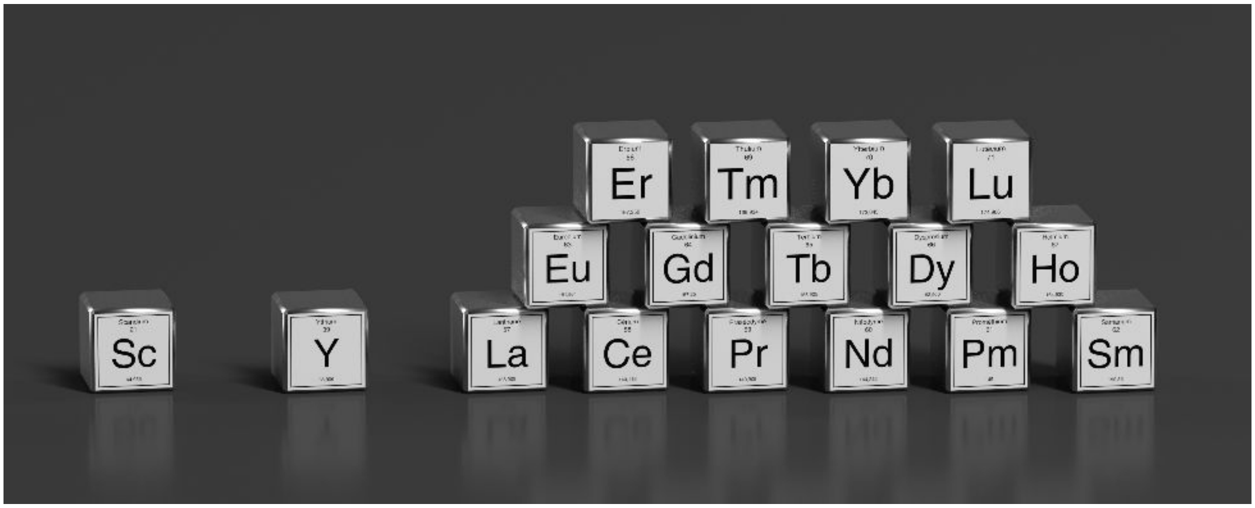
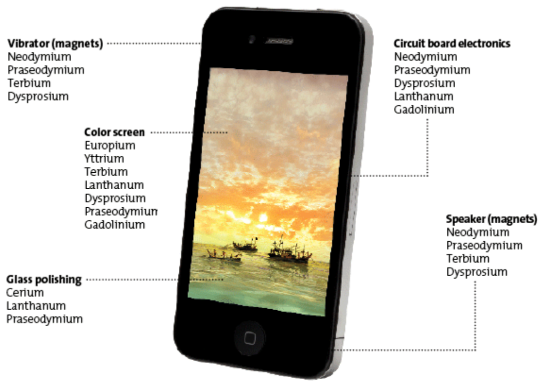


Building a Domestic Rare Earth Elements (REE) Supply Chain – The STS Challenge

For over 27 years, STS has been creating and implementing innovative solutions to many of the United States' most complex defense and national security problems. Today, we are facing the complex challenge critical to our present national security interests of building a domestic Rare Earth Elements (REE) supply chain. Without the ensured supply of REE, the country's economy and national security remains vulnerable to foreign market disruptions and potential defeat on the battlefield. STS has done its due diligence in this market and predicts that the use of prudent business practices is required to solve this complex problem correctly. To apply prudent business practices to this problem requires a source-independent solution which integrates multiple suppliers of REE into a strong and resilient domestic supply chain.

What are REE?

REE include the fifteen members of the lanthanide series plus the two chemically similar elements scandium and yttrium. One member of the lanthanide series, promethium, is chemically unstable and does not occur in nature, so we normally refer to 16 REEs. These elements are often further subdivided into lights (La to Sm) and heavy (Eu to Lu, Y and Sc) REE based on their atomic radius or into groups according to their industrial usage. Such groups include : magnets (Pr, Nd, Sm, Tb, Dy), phosphors (Pr, Eu, Er, Y) and catalysts (La, Ce, Nd). Light REEs are much more common and are easier to extract and refine than heavy REE due to their relative abundance. For the most part, Rare Earth Elements are not 'rare' at all and are quite abundant in the earth's crust. However, few geochemical processes concentrate REE into commercially attractive deposits, so it is difficult to find sufficient quantities of REE in one place to justify investment in a mining and processing facility. Even if a domestic source of REE feedstock were available, the United States has no capacity for



Rare Earth Elements are Critical Components for our Mobile Devices (Source: Huffington Post) refining it into useful materials. Traditionally, most REE refiners limit their operation to the separation of light REE (or LREE) with a few select refiners separating heavier elements, mostly for phosphors and magnet elements. Very few facilities have the capabilities to separate the full suite of heavy REE (or HREE), as such, most HREE are stockpiled as a mixed HREE concentrate. However, the demand for HREEs has recently increased rapidly, drawing down the existing stockpiles.

Why REE Matters

REE are a key component in the construction of clocks, cellphones, and televisions. They enable medical science to examine the human body through x-ray and magnetic resonance imaging. They're used in neutron therapy to target tumors and can be found in cancer fighting drugs. Permanent magnets containing neodymium, gadolinium, dysprosium, and terbium are required to generate power in automobiles, wind turbines and drones, and REE help our military build more capable firearms, missiles and fighter jets. REE help the average American function in the 21st century and ensure our nation maintains a technological edge over our competitors and adversaries around the world.

Powerful rare earth magnets are also important for electric vehicles, and each new wind turbine requires over half a ton of REE. REE are largely imported to the United States as components of devices that are manufactured in foreign countries. The F-35 Lightning II, for example, contains REE components, essentially black boxes, that are manufactured in China.

Figure 1: REE Supply Chain from Mining to Magnets (Source: Advanced Magnet Lab)

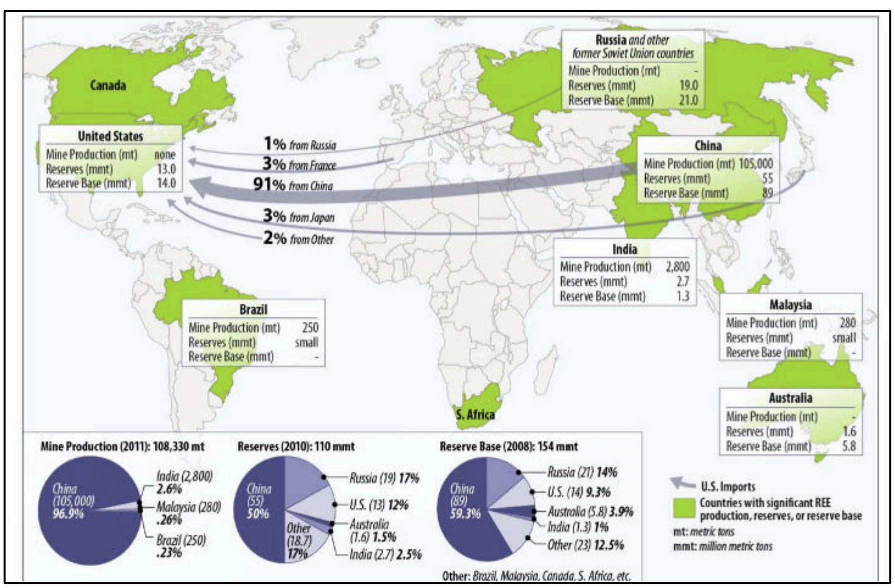
REE are also critical for national defense. While the defense industrial base accounts for less than 5% of U.S. domestic rare earth consumption, these materials are essential for several critical defense technologies.[1] Jet fighter engines, drones, missile guidance systems and many of the communications and night vision devices and optics systems that give U.S. special operations forces their cutting edge require rare earth oxides or alloys. Many of the components that enable 'smart' munitions, such as joint direct attack munitions and other bombs also contain REE.

Military Drones and Precision Munitions Contain Rare Earth Components

Unfortunately, America's domestic capacity to integrate REE based materials and products into the DoD and civilian supply chains is very limited. This precarious situation has left the U.S. substantially dependent on importing processed REE from a single source and from one of its business competitors and strategic adversaries, China. China produces about 95% of the world's REE raw materials, about 97% of rare earth oxides, and is the only exporter of commercial quantities of rare earth metals. About 90% of the metal alloys are produced in China and China manufactures 75% of the NdFeB permanent magnets and 60% of the SmCo permanent magnets. Should China decide to cut off REE exports to the United States, the impact on the American economy and the Nation's security would be severe.

A Tenuous Supply Chain

While REE are critical to national defense and other technologies, the U.S.' REE supply chain is extremely vulnerable to supply disruption from foreign entities. Currently, the U.S. has no operating domestic refining capacity, which is necessary to convert the raw ores into the separated REE oxides, metals and alloys needed for defense and other purposes. Currently, the U.S. has only one active rare earth mine,



The Global Rare Earth Supply Chain (Source: CRS)

[1] Grasso, Valerie Bailey, *Rare Earth Elements in National Defense: Background, Oversight Issues and Options for Congress*, Congressional Research Service, December 23, 2013, page 9.

Mountain Pass. It should be noted, however, that this operation is partially owned (9.9 percent) by a Chinese firm, and it currently exports its mineral concentrate to China for refining.

Globally, China produces about 95 percent of raw rare earth materials and nearly 97 percent of rare earth oxides and metals. It also accounts for the preponderance of the rare earth permanent and samarium cobalt magnets produced.[2] China has used its REE dominance for leverage in the recent trade dispute with the United States and other countries, such as Japan. China also appears to use its rare earth monopoly to manipulate rare earth pricing, making it difficult for private sector companies elsewhere to enter the market and compete effectively.[3] For example, during the 2010 to 2012 Rare Earth Crisis, China reduced export quotas during a period of increased demand. This constrained market caused prices for many REE to increase more than two orders of magnitude, leading to shortages in downstream markets.[4] Later, China increased the export quotas, flooding the market with oversupplied REE and reducing REE prices to historically low levels. Many of the greenfield REE exploration projects initiated in 2010 to 2012 could not produce a long-term business case at these low prices and were subsequently terminated. Despite a global, non-Chinese investment of over $4 billion in those two years, only one new company achieved commercial REE production[5]. This ability of the Chinese to manipulate the supply chain, coupled with increased internal demand, has created a well-defined risk to our national security.

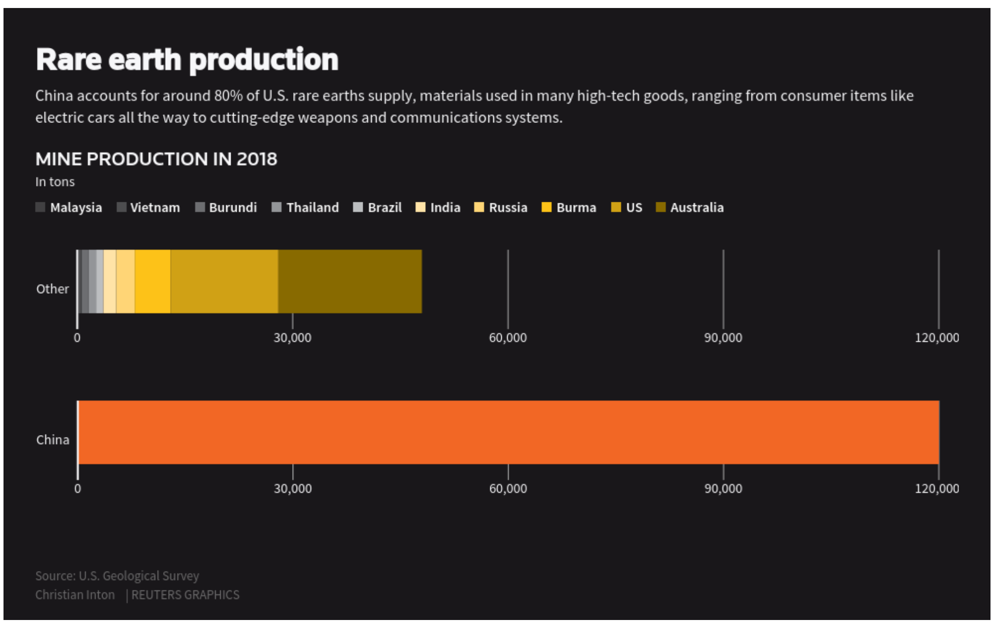


Figure 2: Rare Earth Production. Source: U.S. Geological Survey

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[2] Humphries, Marc, *Rare Earth Elements: The Global Supply Chain*, Congressional Research Service, December 16, 2013, page 14.
[3] Tabeta, Shunsuke, "Rare Earth Wars: China Expands Production to Squeeze US Entrants," *Asian Review*, November 10, 2019, https://asia.nikkei.com/Economy/Trade-war/Rare-earth-wars-China-expands-production-to-squeeze-US-entrants.
[4] Jordens A, Cheng YP, Waters KE. A review of the beneficiation of rare earth element bearing minerals. Miner Eng 2013;41:97–114. doi:10.1016/j.mineng.2012.10.017.
[5] Cox, C., & Kynicky, J. (2018). The rapid evolution of speculative investment in the REE market before, during, and after the rare earth crisis of 2010–2012. *The Extractive Industries and Society*, *5*(1), 8-17.

Over the past two decades, American companies have attempted to address the REE supply chain challenges but have been unsuccessful.[6] However, in nearly every case those companies approached the REE problem from the perspective of the mining industry, only to find themselves unable to operate with the cost efficiencies required to compete against China's REE monopoly. In addition, exploration, permitting and infrastructural needs of a new REE mine would require up to 7 years and hundreds of millions of dollars with an uncertain green light at the end.

A Potential Solution

A source-independent REE separation and processing capability would be a "First of its Kind" facility equipped to receive the widest variety of available REE feedstock ensuring an uninterrupted upstream supply of REE based materials and products to support growing downstream defense and civilian buyers. A commercially viable, domestic supply chain requires redundancies and an independent approach. Providing a unique source independent approach differing and evolving technology requirements more rapidly and effectively than single-source mine plants, which are beholden to their source rock and their largest customers.

Source independence also enhances market sustainability and increases capacity for an ensured domestic HREE supply. In addition, it must be domestically self-reliant, with no foreign dependence, whatsoever, in order to minimize economic and security impacts should a foreign government attempt to disrupt the international HREE supply chain. Conversely, a domestic supply chain which is source-dependent on a single mine presents a very high risk for a single point of failure. Overreliance on a singular separation and processing capability would also have a very risk and potentially cause the collapse of supply chain.

A History of Mission-Driven Innovation

STS has spent the past three decades delivering innovative solutions to complex national security problems. In every single case, the solutions we provided had to be agile enough to adapt to a thinking adversary in an ever-changing security environment, like our current circumstances in the REE industry. For example, a decade ago STS enabled U.S. forces to expand their operational footprint deeper into contested territory in Afghanistan and Iraq providing field service engineering and operations support with the Counter-Rocket and Mortar (C-RAM) system. Additionally, our Vehicle Body Armor Support System (V-BASS) enabled the U.S. military and other government personnel to protect themselves in Iraq and Afghanistan while conducting critical activities in light armored vehicles.

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[6] Green, Jeffery A., "The Collapse of American Rare Earth Mining – and Lessons Learned," *Defense News,* November 12, 2019, ttps://www.defensenews.com/opinion/commentary/2019/11/12/the-collapse-of-american-rare-earth-mining-and-lessons-learned/.

Figure 3: STS has been delivering mission-driven, agile, innovative solutions to the DoD for almost 30 years.

STS' original technical solution in 1995 – the Portable Uninterruptable Power (PUP) system, was a first-of-its kind solution which enabled military forces to reliably operate critical electronics at austere locations, a critical factor in modern military operations. We developed many of these systems iteratively, adapting to the needs of the Department of Defense and the evolving threat our military service members faced on the battlefield. Now, STS is bringing our mission-driven innovative approach to the REE supply chain problem.

Strengthening the Domestic REE Supply Chain

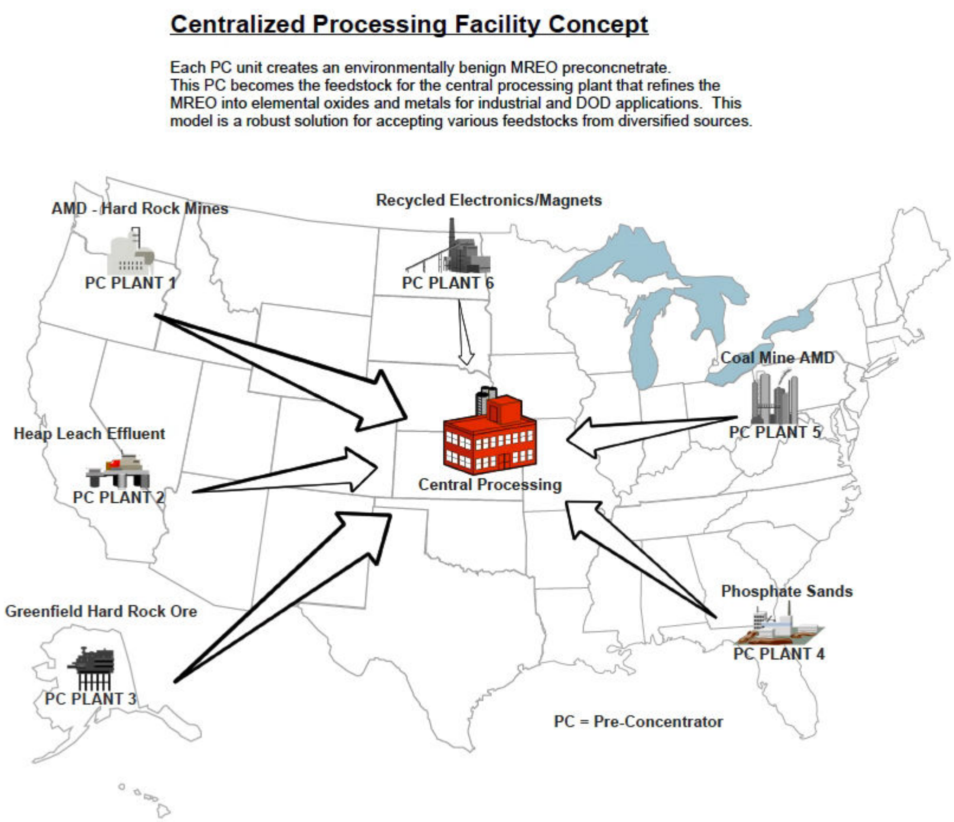
STS began working in the REE industry five years ago when we assessed opportunities to mine the Khanneshin carbonatite deposit in Afghanistan's Helmand province, a major REE element deposit. That initial inquiry drove us to explore the current supply chain and the complexities of successfully entering the REEs sector and competing with China.

Since then, STS has built a network of like-minded government officials and policy experts, geologists and mining experts, engineers, academics and think tanks to develop comprehensive solutions to the domestic REE supply chain. We are closely studying every step of that supply chain and are preparing to field commercially viable, innovative solutions to REE feedstock that will support the defense industrial base and essential civilian supply chain. Furthermore, some of our partners are already exploring elemental REE separations, resulting in a significant first-mover advantage into the domestic supply-chain.

Specifically, we are looking at techniques to separate REE using methods that do not require any traditional mining at all, from coal and hard rock acid drainage to the recycling of commercial electronics. This novel approach would allow almost immediate startup while bringing on multiple sources of high-grade HREE feedstock into a centrally located refining facility. STS envisions satellite pre-concentrators at suitable locations around the United States feeding a +90% pure mixed-oxide to a central processing facility where the oxides would be separated into individual REE oxides and refined into metals, and ultimately usable products. This hub and spoke concept would allow rapid deployment of heavy REE production using acid mine drainage while bringing additional HREE sources on line. This will provide supply flexibility, minimal transportation costs and a focus on heavy REE production.

Acid Drainage Rare Earth Extraction pilot plant at West Virginia University

In addition, these sources of HREE would also yield LREE products that are considered critical defense materials such as the magnet elements neodymium, praseodymium and samarium.



Schematic diagram indicating how a variety of HREE feedstocks can supply pre-concentrates (PC) into a centralized processing facility for elemental separation and metal refining for defense applications.

The objective of a source-independent solution is to produce all the REE products that the defense industrial base and essential civilian supply chain need – the rare earth oxides metals, alloys, and permanent magnets – to blunt China's ability to threaten the global REE supply chain. This robust domestic REE supply chain must be commercially competitive, and give overseas manufacturing firms an alternative, competitively priced source of REE products.

To provide a robust and uninterruptable domestic supply of REE elements to the defense industrial base and civilian supply chain is a major undertaking that requires access to innovation, creativity, global business and political acumen, secure organizational practices, defense industrial base, and supply chain expertise. With almost 30 years in the defense and emerging technology business, STS is well positioned to play a major role in the REE industry. We approach this problem as an opportunity to apply our expertise in the defense industry, technology, and business and deliver an integrated, secure solution that ensures a viable, resilient domestic REE supply chain to protect our national security interests.