Symposium on Strategic Materials

12 June 2012

College Park, Maryland

Symposium Report
Prepared for Iktara & Associates, LLC
by
Elan Moritz, Ph.D.

Contents

Executive Summary

This document reports on the discussions, conclusions, and recommendations emerging from the First University of Maryland – Center for Energetic Concepts Development Symposium on Strategic Materials. The Symposium is part of an assessment arising from concerns over reliable availability of certain materials that have a potential to impact national economic security and national military security. In particular, it is oriented to add perspectives to the Defense Laboratory Enterprise (DLE) Office within the Assistant Secretary of Defense, Research and Engineering (ASD(R&E)) organization with the aim of helping ascertain and ensure that the defense labs are properly focused on scientific trends of interest and emerging technologies. Under its "Global Science and Technology Insight" imperative, DLE is exploring how defense labs can assist in addressing technology gaps that may be associated with international developments and potential shortages in strategic materials.

The Symposium documented in this report focused on rare earth elements, and on the specialized batteries and fuel cells materials and technologies. Recognized industry, academic, and government subject matter experts presented focused briefings as keynote addresses in the morning sessions; panel sessions were conducted in the afternoon to allow additional perspectives and substantial interaction between the panelists and all the symposium participants.

Certain observations and conclusions merit attention. The concern regarding availability of strategic materials, including rare earth elements and certain precious metals, is indeed legitimate, as well as the concern over supply and availability concentrations dependent on very few (and sometimes only one) foreign sources. In all cases, the overall economy is the driver of rare earth elements and strategic material utilization, not DOD, (for example, the automotive and electric grid energy generation and storage will dominate the economics and materials availability considerations for batteries, fuel cells, and permanent magnet motors). However, the overall economy is not compelled to provide cost reliable and timely supplies to the DOD industrial base. There are several government organizations that track, estimate, and even stockpile strategic resources, however, the strategic and critical elements of yesterday may not be strategic and critical today, and what is strategic and critical today may not be tomorrow, so understanding and possibly driving the technologies of tomorrow will allow better forecasting and reducing availability risk of future strategic and critical materials.

Industrial mining initiatives such as Molycorp's Project Phoenix will increase domestic rare earths elements' availability. New fuel cell and battery technologies are poised to favorably impact strategic and critical material availabilities, in particular, precious metals such as platinum.

There are several worthwhile national scale initiatives that can improve the U.S., and DOD's robustness and resilience associated with batteries and fuel cells. These include policies and technologies associated with strategic and critical materials recycling, increasing (at plant) hands-on-engineering experience for engineering students, advanced material science (dual doping, engineered nanostructures, increasing material purities and, focusing on replacing specific high performance elements such as platinum and dysprosium). Also suggested is consideration to developing government and industry consolidated roadmaps providing visibility of strategic and critical materials availability, expected needs, and key perceived mitigation challenges and initiatives underway.

1. Background

The First University of Maryland – Center for Energetic Concepts Development Symposium on Strategic Materials was held on 12 June 2012 at the Inn and Conference Center facilities located on the University of Maryland College Park Campus. The Symposium is part of an effort at strategic materials assessment arising from concerns over reliable availability of certain materials that have a potential to impact national economic security and national military security. In particular, within the Defense Department, attention has been focused on identifying new sources of strategic materials deemed to be in short supply for production of critical defense systems.

The Defense Laboratory Enterprise (DLE) Office within the Assistant Secretary of Defense, Research and Engineering (ASD(R&E)) organization has the responsibility to ascertain and ensure that the defense labs are properly focused on scientific trends of interest and emerging technologies. Under its "Global Science and Technology Insight" imperative, DLE is exploring how defense labs can assist in addressing technology gaps that may be associated with international developments and potential shortages in strategic materials.

To this end, the Center for Energetic Concepts Development (CECD) at the University of Maryland, College Park is conducting a study on strategic materials and components including:

- Rare earth elements
- Battery materials
- Alternative energy chemical catalysts
- Energy source materials
- Materials used in production of weapons, i.e., explosive and propellant primary ingredients

Using insights gained from various sources and experts, recommendations will be offered for research programs to develop additional approaches and alternatives to the above materials where appropriate. Resulting programs will be structured for execution within consortia of academia, DOD laboratories, DOE laboratories, FFRDCs, UARCs[1] and industry.

The June 2012 Strategic Materials Symposium documented in this report focused on rare earth elements (REEs[2]), and on the specialized materials in batteries and fuel cells. The Symposium was organized to provide balanced perspectives and insights by experts from industry intimately and directly involved with rare earth elements, batteries, and fuel cells, prominent academic investigators, as well as Government and DOD experts. Keynote speakers presented focused briefings as keynote addresses in the morning; panel sessions were conducted in the afternoon to allow additional perspectives and substantial interaction between the panelists and all the participants. This report documents the key

[1] DOD - Department of Defense, DOE – Department of Energy, FFRDC- Federally Funded Research and Development Center, UARC – University Affiliated Research Center

[2] There are other abbreviations often used in conjunction with REEs, these include: RE = rare earth, REM = rare earth metals, REO = rare earth oxides, REY = rare earth elements and yttrium, LREE = light rare earth elements (La-Eu; also known as the cerium group) and HREE = heavy rare earth elements (Gd-Lu and Y; also known as the yttrium group) – see < http://en.wikipedia.org/wiki/Rare_earth_element>

insights and points raised in the briefings and panel discussions, and where possible, reproduces the briefing materials and additional perspectives provided by participants after the symposium.

As a note, there are many documents discussing rare earth elements. A recently completed book surveying some key trends and discussing issues and concerns, *Rare Earth Elements: Insights and Concerns*[3], published recently by the Center for Energetic Concepts Development, was distributed at the symposium.

Those wishing an introduction to some of the publicly known dependencies of US weapon systems on rare earth materials may wish to look at papers such as Hedrick's *Rare Earths in Selected U.S. Defense Applications*[4]. The account below is an abridged version of some of the uses Hedrick points out.

"Samarium-cobalt permanent magnet motors direct the moving flight control surfaces in the AIM-9 "Sidewinder," the AIM-54 "Phoenix," and AIM-120 AMRAAM. The AIM-9 "Sidewinder," has four fins mounted on the forward section of its fuselage that control its flight trajectory with rare-earth magnet motors. The AIM-54 "Phoenix" is directed by samarium-cobalt motors positioning the fins at the rear of the missile. … Movable flight surfaces of the AIM-120 are mounted mid-fuselage and are directed by samarium-cobalt actuators. The AGM-84E SLAM (Standoff Land Attack Missile) missile …is directed by rare-earth-controlled fin actuators that are mounted mid-fuselage … 88 HARM (High speed Anti-Radiation Missile), an anti-radar missile … fins are controlled by rare-earth magnets that direct the missile."

Similar situation obtains with the Stinger handheld missile, the BGM-109 Tomahawk, the Joint Direct Attack Munitions (JDAM) "smart bombs" family that use neodymium-iron-boron magnets to control the drop. This is also true of the Global Positioning System Aided Munitions (GAM) GBU-36/B (2,000-lb) and the GBU-37/B (4,500-lb) penetrator.

"Rare Earth Elements are extensively used in battlefield optics, communications, radar and sonar systems, and various countermeasure systems. Notable are the neodymium:yttrium-aluminum-garnet (Nd:YAG) lasers (found in rangefinders, target designators, and target interrogators, line-of-sight communication). Traveling wave tubes and klystrons use rare-earth magnets in their waveguides. Erbium-doped fiber and fiber amplifiers are used in high-capacity fiber optics. Terbium-iron-nickel alloy with dysprosium (Terfenol-D) is used in stealth technology in helicopter rotor blade quieting and as a transducer material for underwater sonar applications. Samarium-cobalt permanent magnets are used

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[3] M. G. Pecht, R.E. Kaczmarek, X. Song, D.A. Hazelwood, R. A. Kavetsky, and D.K. Anand, Rare Earth Elements: Insights and Concerns, CALCE EPSC Press, University of Maryland, College Park, MD, 2012.

[4] J. B. Hedrick, Rare Earths in Selected U.S. Defense Applications, presented at the 40th Forum on the Geology of Industrial Minerals, May 2-7, 2004, Bloomington, Indiana <http://www.usmagneticmaterials.com/documents/RARE-EARTHS-IN-US-DEFENSE-APPS-Hendrick.pdf>

in aircraft generators. Similar to use in missiles, small high-powered rare-earth magnet actuators are used to move flight control surfaces of aircraft, including flaps, rudder, and ailerons. Yttria-stabilized zirconia, a high-temperature resistant ceramic coating, is used as a thermal barrier in the “hot” sections of jet engines to protect the metal alloys in the Pratt & Whitney F100-PW-229 turbofan engine for the McDonnell Douglas Corp. F15 Eagle and the Lockheed Martin F16 Fighting Falcon fighter jets.

… Flat Panel Displays utilize glass panels or substrates that are polished with cerium oxide. Avionic displays use terbium-doped gadolinium oxysulfide and lanthanum oxysulfide phosphors for high-luminescence. Yttrium-iron garnets (YIG) and yttrium-gadolinium garnets (YGG) are in phase shifters, tuners, and filters. These systems are used in the PATRIOT (Phased Array Tracking to Intercept of Target) air defense missile system’s guidance and radar control group and in other systems’ magnetron tubes used in ground-based systems for air traffic control and surveillance radars, search radars, and weapon fire-control radars.

…. Gadolinium metal applied as paint or coating, was used as a defensive measure against neutron radiation. Cerium-based compounds are used as polishing media for many types of optical lenses encountered in the battlefield. Many of these lenses also contain the additive lanthanum oxide, to increase light refraction and decrease dispersion. Precision polished optical lenses are used for ranging, targeting, observation, detection systems, countermeasures, photography, and protection from harmful laser wavelengths, flashblindness, UV and reflected light. Rare earth-containing optics are used in binoculars, rifle scopes, laser targeters and designators, telescopes, microscopes, protective eyewear, rangefinders, night-vision equipment, camera lenses, filters, and protective lenses.

… Terfenol-D rare-earth alloy is replacing piezoceramic materials in several systems due to its exceptional response (response to a magnetic field is 200 times faster than a mechanical device. It also has recently been designed for use as a diesel fuel injector, adjusting its size almost instantaneously to dispense the proper amount of fuel. Neodymium-iron-boron permanent magnets are used in many defense systems. Designed to withstand vibration, impact, and g-forces, rare-earth disk drive motors and actuators are installed in aircraft, tanks, missile systems, and command and control centers.

… Rare earths, including gadolinium, yttrium, and samarium are used in several electronic counter measures.”

Clearly then, there has been and continues to be substantial use of strategic materials and rare earth elements in critical defense applications. Frequent and substantive visits and revisits of issues associated with reliable availability and possibilities for alternative materials and technologies to mitigate supply and availability gaps are in order.

2. Symposium Agenda

0800 Registration

<u>Introduction and Theme Setting</u>

0900 Dr. John Fischer, Director, Defense Laboratory Office (OSD)

Dr. James Short (CECD)

<u>Keynote Speakers</u>

0915 Mr. David Cammarota (OSD)

0945 Mr. Andy Davis (Molycorp)

1015 Prof. Gregory Jackson (University of Maryland)

1045 Dr. Christopher Guzy (Ballard)

1115 Break

1130 Prof. Robert Moore (Virginia Tech)

1200 Dr. Kamen Nechev (Saft Groupe SA)

1230 Group Picture and Lunch

<u>Panels</u>

1400 Rare Earth Elements Panel

1445 Batteries Panel

1530 Fuel Cell Panel

1615 DOD Users Panel

1655 Concluding Remarks

1700 Reception

3. Introduction and Theme Setting: Dr. John Fischer, Director, Defense Laboratory Office (OSD) and Dr. James Short (CECD)

Dr. John Fischer, Director, Defense Laboratory Office, opened the symposium with brief introductory remarks regarding the policy, base budget and resource responsibilities of the Defense Laboratory Office. Dr. Fischer highlighted the focus of the office on making sure that DOD and the DOD laboratory enterprise maintains Global Science and Technology Insight, and very importantly, that the DOD laboratory enterprise does not stop conducting research and development that is vital to the nation due to oversight or lack of appreciation of the significance and continued importance of key areas.

A key objective for the office is identifying problem areas and technologies that are of strategic importance to national military security within DOD's scope of responsibility. With respect to strategic materials and components including, rare earth elements, battery materials, alternative energy chemical catalysts, energy source materials, and materials used in production of weapons (i.e., explosive and propellant primary ingredients), questions can be framed as: "Do we look for new sources of existing materials, or do we look for new materials with 'good enough' properties (to substitute/replace increasingly rare and costly materials)?"

Examples of emerging issues include geopolitical issues associated with Congo and their impact on availability of magnet materials using cobalt and samarium (sourced in the Congo), as well as recent uncertainties of supply availabilities of key rare earth elements (principally mined and processed in China) in the face of increasing worldwide demand.

Dr. Fisher shared some questions with the participants, among those were:

i. What are the REE alternatives? Are they becoming harder to get?
ii. What would a national program for REE alternative materials look like?
iii. Are there additional national strategic imperatives associated with the REE, battery materials, fuel cell components that we should be addressing?
iv. How can we improve transition of results (and knowledge gained in) government funded programs (i.e. funded by DOD in academia and the Defense Laboratory Enterprise), into private sector commercial and manufacturing activities. This is particularly important in view of the fact that venture capital investments into research and development (R&D) have declined over the years, while the U.S. government has pumped billions of dollars into R&D. How does the nation put this investment to effective use as part of the private sector economy?

Prof. James Short provided a short introduction to the CECD and University of Maryland vision and activities. Prof. Short highlighted the University's vision of becoming and achieving World Class University status, its interest and progress in expanding international influence (noting 50 agreements currently in place with China) and, the University's commitment to excellence through addressing great and challenging problems and advancing science and technology.

Prof. Short provided some impressive University of Maryland statistics (in top 20 of public universities in USA, 26,000 undergraduate and 11,000 graduate students, 3,000 full time faculty, $1.6B total budget, and $400M in contracts and grants). Also provided was a short orientation to the Center for Energetic Concepts Development (CECD), its origin with the goal of fostering continued advancements in energetics manufacturing and science, while educating the next generation of energetics experts. Prof. Short provided a brief glimpse into some of the ongoing research initiatives at the CECD including R&D in energetic materials, virtual environments, hazard assessment, and traumatic brain injury, as well as a few remarks regarding the uniquely specialized energetics courses in shockwave physics, combustion and reacting, chemistry of energetic materials, MEMS (microelectromechanical systems), rocket propulsion and the overall graduate energetics program. CECD's energetics graduate program is unique in the nation in the depth of formal training in energetics; the program's availability as an online program was briefly discussed as well.

Prof. Short concluded the Symposium's opening remarks by posing some general questions that would serve to motivate the informal discussions and the afternoon's panel sessions. The key theme setting questions posed were:

Question 1 – Given your experience, what are the rare-earth material-related technology gaps for batteries, fuel cells, and other critical components?

Question 2 – How should your organization best be involved in these activities either as a technology organization or end-user?

Question 3 – What additional R&D initiatives need to be created to develop alternatives to rare earth materials and other critical materials?

Aspects of these questions were addressed in the keynote presentations as well as in the afternoon panel sessions.

4. Keynote Presentation by Mr. David Cammarota (OSD)

Mr. Cammarota, the materials specialist within the Office of Manufacturing and Industrial Base Policy at the Department of Defense, introduced and discussed perspectives associated with Section 853 of the 2012 Defense Authorization Act (see Appendix A: Assessment of the Feasibility and Advisability of Establishing an Inventory of Rare Earth Materials Necessary to Ensure the Long-term Availability of such Rare Earth Materials). Section 853 provides congressional recognition of the seriousness of rare earth elements supply ambiguities, and direction to clarify and explore options and alternatives. This is where additional discussion and options merit a closer look as the idea of 'stockpiling' may include concepts like 'rolling inventories' as well as 'producer managed inventories'.

Mr. Cammarota referred to several interagency efforts. For example, the White House Office of Science and Technology Policy (OSTP) established a Subcommittee on Critical and Strategic Mineral Supply Chains [5]. Some of the interests of the interagency committees are to assess data availability and data gaps, research and development efforts and needs, as well as criticality assessments and identification of emerging materials requirements.

Mr. Cammarota reflected that the overall economy is the driver in REE and strategic material utilization, not DOD. For example, the share of U.S. consumption of titanium by the defense industrial base is only six or seven percent by some estimates, yet this represents one of the largest market shares held by the defense industrial base for a material. DOD share of utilization of other materials is much lower. The mission of the DOD Office of Manufacturing and Industrial Base is to ensure that there exists an innovative industrial base which is capable of meeting the needs of the warfighter in a timely, reliable, and cost effective manner.

As a personal observation of a person following the REE and strategic materials industry for over thirty years, and looking at previous history, Mr. Cammarota noted that there appears to be a twenty-year cycle of interest in strategic materials in Washington, DC. As a timeline, in 1951, President Truman established the President's Materials Policy Commission (Paley Commission) indicating that, "WE cannot allow shortages of materials to jeopardize our national security nor to become a bottleneck to our economic development." Congress established the National Commission on Materials Policy in 1970 for the purpose of developing a national materials policy (a report was issued in 1973). In 1980, Congress passed the national Materials and Minerals Policy, Research and Development Act to, inter alia,

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[5] From the U.S. HOUSE OF REPRESENTATIVES COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY, Subcommittee on Energy and Environment December 7, 2011 Hearing 'Energy Critical Elements: Identifying Research Needs and Strategic Priorities.' "OSTP created a new Subcommittee on Critical and Strategic Mineral Supply Chains, with the purpose to "advise and assist [OSTP] on policies, procedures and plans relating to risk mitigation in the procurement and downstream processing of critical and strategic minerals. Functions of the Subcommittee include identifying critical and strategic minerals and identifying cross-agency research and development opportunities. … Participants in the working group include the DOE, Department of Defense (DOD), USGS, Department of Commerce, Environmental Protection Agency, Department of Justice, Department of State, and the U.S. Trade Representative."

establish an early warning system for materials supply problems. Today, we see many of the same types of legislation being introduced in Congress. Mr. Cammarota's concern was that it appears that once the issue generating the interest in strategic and critical materials is resolved, the subject is relegated to the back burner. He expressed an interest in ideas regarding the means of institutionalizing a government-wide, interagency effort to continuously focus on the importance of materials to future economic prosperity and national security including assessing their supply chains, and ensuring their availability. He also noted that the materials of concern that generated interest in strategic materials in each of these interests were not necessarily the same. What was strategic and critical yesterday may not be today, and what is today may not be tomorrow, and we need to keep an eye out for what may be the critical issues of tomorrow.

Mr. Cammarota mentioned the NNMI-National Network for Manufacturing Innovations going from lab-to-market, as a new initiative deserving close attention. Also mentioned was section 901 (see Appendix B for details on Section 901 of H.R. 4310: National Defense Authorization Act for Fiscal Year 2013– "additional duties of deputy assistant secretary of defense for manufacturing and industrial base policy and amendments to strategic materials protection board" This section would amend section 139c of title 10, United States Code, by directing additional duties of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy. The duties would include prescribing policies and procedures for ensuring reliable sources of materials that are critical to national security. This section would also amend section 187 of title 10, United States Code, by reconfiguring the Strategic Materials Protection Board to include: the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy; an official within the Defense Logistics Agency with responsibility for strategic materials; and designees from the Army, the Navy, and the Air Force.)

5. Keynote Presentation by Mr. Andy Davis (Molycorp)

Mr. Andy Davis, Molycorp's Washington office government and public relations manager, presented a keynote briefing titled Molycorp: *Diversity of Supply through Technology Innovation.* As background, Molycorp is the principal U.S. provider of domestically mined and processed rare earth elements. Domestic production is concentrated at Molycorp's Mountain Pass mine in California. Mr. Davis communicated that the day before the Symposium, Molycorp announced that it closed on its $1.3 billion acquisition of Canada's Neo Material Technologies Inc., and consequently the keynote would also incorporate Neo Materials related perspectives and insights. With this acquisition Molycorp enhanced its global operations and its vertical integration of rare earth elements related products from ore to finished goods. Mr. Davis' discussion focused on four major aspects:

- Rare Earths 101: Applications and Supply/Demand Projections
- Project Phoenix Update: Mountain Pass On Track
- Molycorp + Neo Materials: A Fully Integrated Global Producer
- Proprietary Technologies: Molycorp's Competitive Advantage

Molycorp produces the rare earth elements cerium, lanthanum, praseodymium, neodymium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium, and yttrium commercially. In addition to mining and processing these materials, Molycorp is focusing on product applications critical to enabling high value technologies as a result of unique attributes of rare earth elements, compounds, and alloys that allow greater efficiencies, miniaturization, durability, and thermal stability ending up in improved performance for many sectors, in particular for defense applications, green energy hybrid electrical vehicles and water treatment.

Molycorp's internal forecasts suggest that third party REE availability forecasts are overly optimistic in view of China's domestic demands. Mr. Davis displayed the Molycorp forecast shown in Figure 1. Molycorp's estimate of REE market demand shows magnets, phosphors, metal alloys, ceramics, polishing, catalysts, and glass dominate the demand by application for REOs, with magnets, metal alloys and catalysts being the three principal application areas.

Mr. Davis provided an update on Molycorp's Project Phoenix at Mountain Pass. Project Phoenix is on track to produce over 19,000 tons of rare earths per day at the conclusion of Phase 1 (Q4 2012), and 40,000 tons per day at conclusion of phase 2 (mid 2013). Currently, Project Phoenix is mining 2,800 short tons of fresh ore per day, 4 days a week. The production circuit includes crushing, blending, cracking, milling and paste tailing handling and disposal. In the near term, Molycorp will complete a full-size, multi-stage cracking facility, solvent and heavy concentrate production, rare earth oxide separation, and product finishing. Some of the product concentrates will be stockpiled for production purposes. Notably, due to its prevalence and co-extraction with the heavier REEs, significant amounts of cerium will become available.

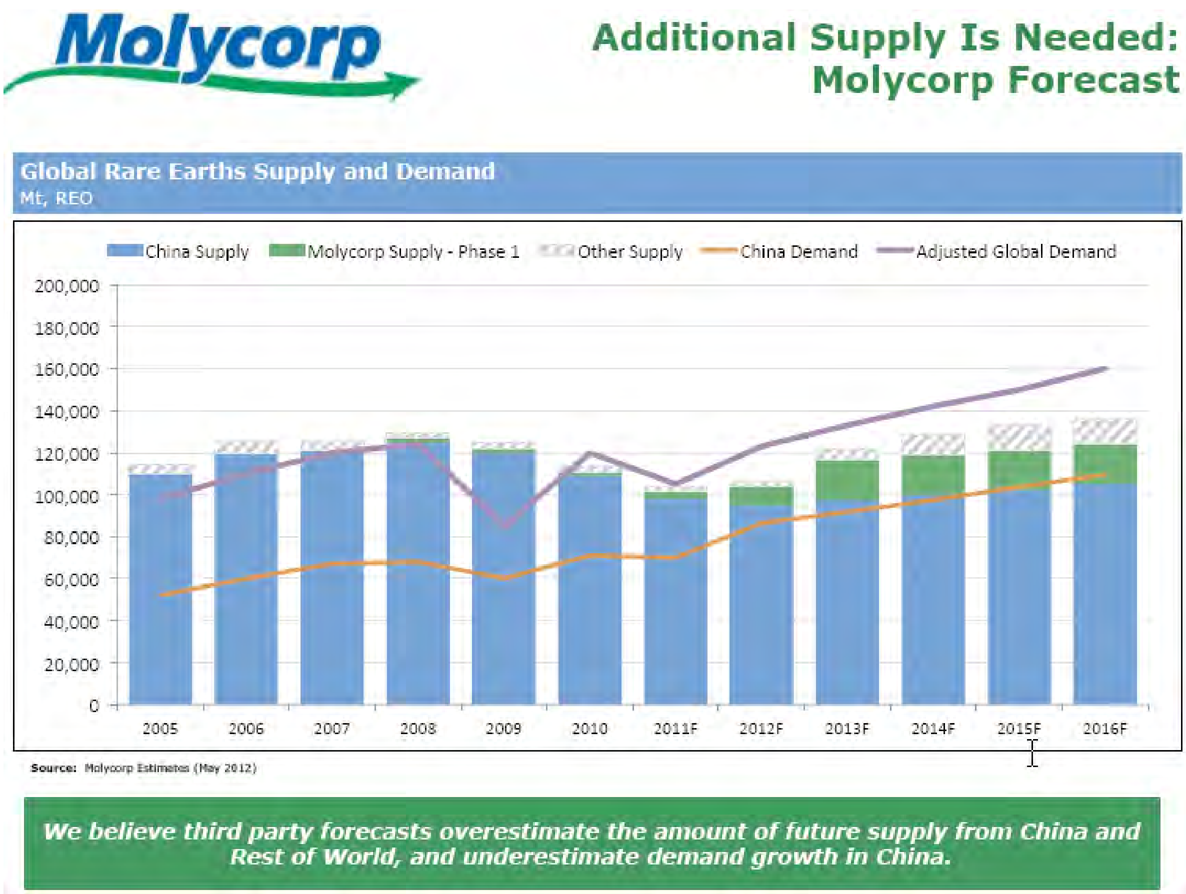


Figure 1 – Molycorp forecast showing China's demand will exceed China's supply of REEs starting about 2015.

Mr. Davis communicated that as a result of Molycorp's strategic analysis and proprietary technology planning and acquisition, Molycorp is now able to utilize cerium in its XSORBX™ water purification technologies at a price competitive with the overall water purification market, thus providing a potentially very large outlet for cerium, and thereby making the overall economics of REE mining and processing at Mountain Pass very attractive compared to previous years. This approach was a result of Molycorp's CTO and CEO projections of decreasing exports from China. These projections lead to decisions that Molycorp was to:

- Be a low cost producer,
- Be superior environmentally (based on CEO Mark Smith's experience with UNICAL as an environmental issues attorney), and
- Develop a marketable use for the large amounts of cerium which in all cases would be part of the raw ore mining operations, and would need to contribute to the economics of the production. The technical 'breakthrough' there was the recognition that cerium would bond with phosphates and arsenic, and would have significant potential impact in water purification.

Another use for cerium is in fuel cells; this and water purification applications would balance the facts that the heavy REEs have a small annual market (500 tons). Mr. Davis also pointed out Molycorp's thrust into extremely high purity REE processing is expected to open up new, high-value niche markets associated with multi-layer ceramic capacitors, improved phosphors in energy efficient lighting, medical and, military devices. The recent acquisition of Neo Materials is expected to allow even greater purity REEs to be produced with yet additional high value niche market potential in wireless, light emitting diode (LED) and flat panel displays, catalysts, solar energy, and super alloy applications. Molycorp's Intermetallics is expected to allow next generation enhancements to magnet technologies with greater yields using smaller quantities of dysprosium, and greater magnet production yields. Molycorp's Boulder Wind Power Initiative is exploring innovative permanent magnet technology that does not use dysprosium, and is looking to obtain 30% lower levelized cost of energy compared to currently employed geared and direct drive designs.

Mr. Davis communicated Molycorp's perspective of challenges associated with commercial entry and success in the rare earths industry. These include barriers to entry consisting of availability of high ore grade to start with, ability to process the ores, and ability to meet customer specifications. Metal making is a major hurdle due to the fact that environmental permitting is immensely difficult if not impossible today in the US and Western countries (leaving China as the overwhelmingly predominant metal maker; this though may get more complicated as China is increasingly paying attention to environmental issues associated with REEs). What is making it extremely difficult today for many companies is the changing customer focus, with most advanced technologies requiring very high purity products, and even ultra-high purity products.

Mr. Davis concluded his keynote by highlighting that with the Neo Materials acquisition and with Project Phoenix, Molycorp has entered a new corporate phase, being a global company, able to produce and deliver much larger quantities of rare earth element products with increasingly greater purities that will facilitate new and advanced technology applications. A significant take away from this keynote is that better understanding of possibilities associated with ultra-high purity rare earth elements, compounds, and alloys is merited, as these may mitigate increasing costs, and lower worldwide net available supplies.

6. Keynote Presentation by Prof. Gregory Jackson (University of Maryland)

Prof. Jackson presented the Strategic Materials Demands for Fuel Cells and Fuel Processing keynote prepared by him and Prof. Eric Wachsman of the University of Maryland. The keynote focused on various aspects of Solid Oxide Fuel Cell (SOFC) and Proton Exchange Membrane Fuel Cell (PEMFC) architecture, materials, and detailed design. From a national energy supply and utilization perspective, fuel cells have a growing role. Specific national level opportunities are associated with central electrical grid power generation and storage applications where SOFC can also provide carbon capture benefits in addition to their primary power generation potential. These are of substantial interest to the Department of Energy, as are other technologies that 'pull CO_2 out of the air'.

Likewise, there is significant potential for distributed power with combined cooling/heating for SOFCs and PEMFCs (associated with commercial and residential applications currently relying on coal and natural gas), and of course there is significant untapped potential for H_2 fueled PEMFC vehicles (in transportation sector currently relying strictly on internal combustion engines using petroleum products). Prof. Jackson remarked that the automobile industry itself is 'ready' for H_2 but the infrastructure for H_2 is not there. Nissan and Toyota for example are optimistic about the H_2 fueled cars. Of interest to both options (the fuel cell option and battery/hybrid vehicle option) is the fact that the way 'gasoline mileage' is computed, it excludes stop/go conditions at traffic lights.

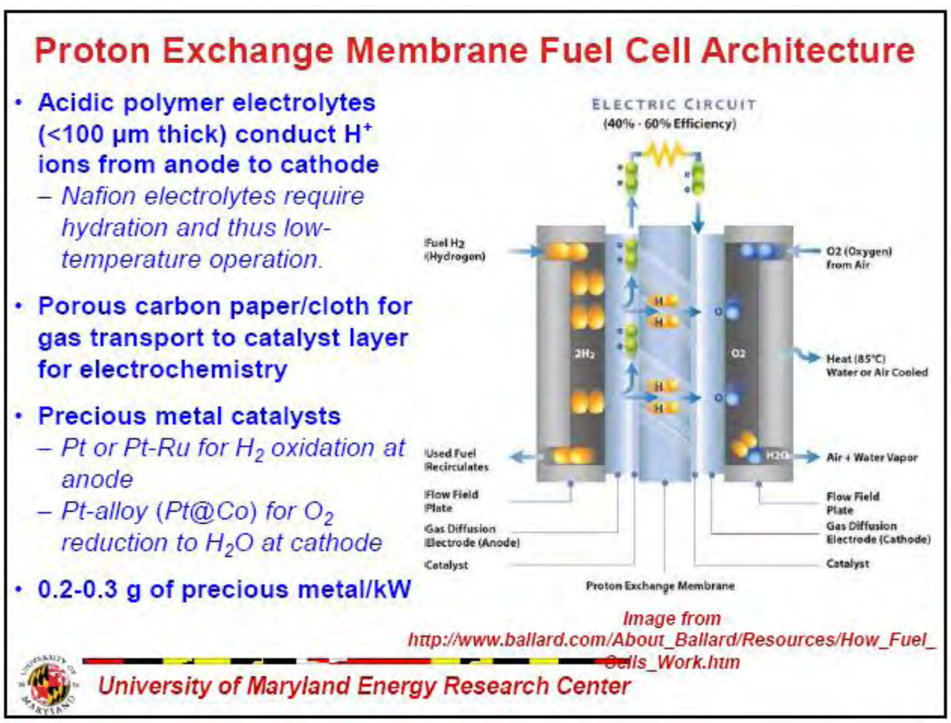


Figure 2 - Proton exchange membrane fuel cell architecture

Legislation currently on the books will mandate incorporating the stop/go conditions for computing miles/gallon metrics in 2015. This will likely accelerate demand for hybrids and electric vehicles, increasingly driving up the need for strategic materials and precious metals.

To better understand the basic architecture and design of SOFCs and PEMCs, Prof. Jackson discussed the SOFC and PEMC architectures shown in Figure 2 and Figure 3.

Some key technical considerations to keep in mind is that while PEMC do not rely on rare earths, they do rely on precious metals due to the hydration/low temperature operation needs where platinum and platinum alloys are needed for 0_2 reduction. As a rule of thumb 0.2-0.3 g of precious metal are required per kW power produced. In contrast SOFCs require temperature gradients (currently 700-800^{o}K ΔT, trying for 500^{o}K ΔT) and do utilize rare earth elements.

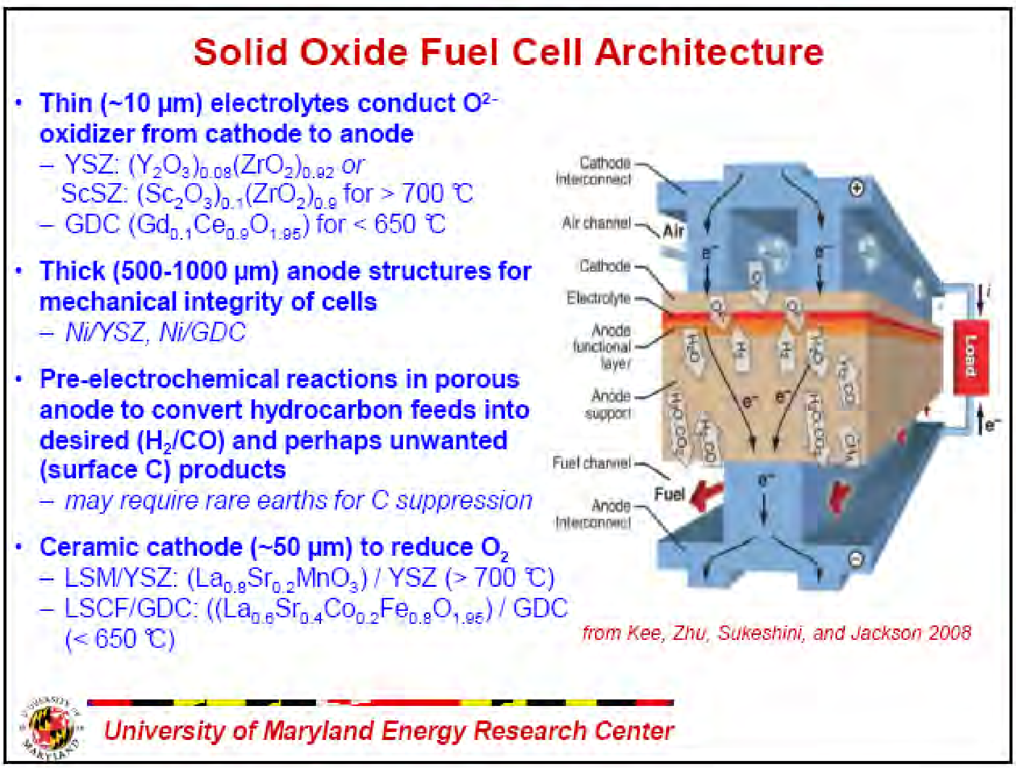


Figure 3 - solid oxide fuel cell architecture

The main takeaways from these architectures relevant to strategic materials considerations is that rare earth elements are in fact used by Solid Oxide Fuel Cells, namely – scandium, yttrium, lanthanum, cerium, gadolinium, and samarium, and that cerium and lanthanum are used as fuel processing catalysts. While not often discussed in the context of strategic materials, the increasing utilization of precious metals deserves mention. The PEM Fuel Cells make substantial use of platinum. Platinum, palladium, and rhodium are often used as fuel processing catalysts and metallic membrane materials. Cerium oxide is often used as a catalyst support material in fuel processing reactors.

Prof. Jackson discussed a 1-5 kWe prototype PEM fuel cell system for hydrocarbon fuels designed by Ballard in collaboration with UMD. This design is geared for military and other stationary power use, and *may* end up employing rare earth elements and precious metals outside the stack (rhodium in the steam reformer, cerium in the reformer and/or water-gas-shift reactor, and platinum in the burner and in the preferential CO oxidation [PrOx] reactor for making relatively pure H_2 [< 20 ppm CO]). SOFC designs may also end up using strategic materials outside the stack.

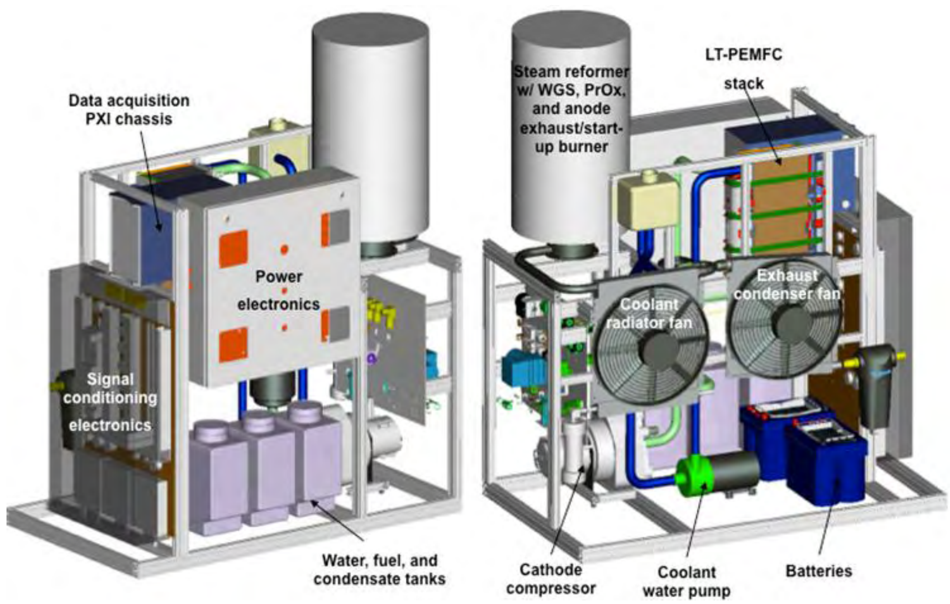


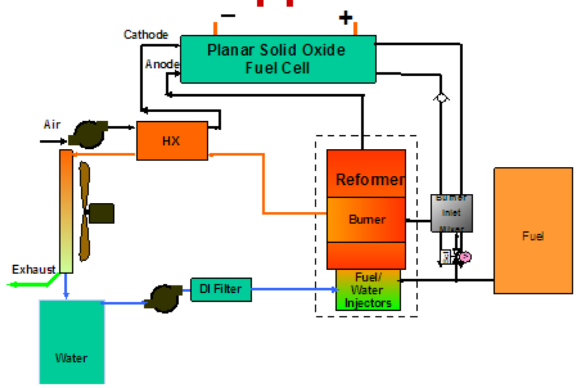
Figure 4 – Ballard/UMD system for 1-5 kWe prototype PEM fuel cell system for hydrocarbon fuels

Prof. Jackson described various approaches for precious metals and strategic materials reduction, for example in membrane reactors; one could obtain process intensification by combining membranes with a unique water-gas-shift reactor to reduce palladium membrane and water-gas-shift catalysts requirements.

Also illustrated and discussed were specific concepts and tradeoffs for fuel cells in unmanned vehicle use. Figure 5 depicts a SOFC for small unmanned aerial vehicle applications. What SOFC considerations using high conductivity electrolytes reveal is that the better the reactivity, the lower the stability thus motivating reactivity/stability tradeoff and innovation. What emerged from investigations was that double doping leads to better conductors (double-doping randomizes oxygen sub-lattice and also stabilizes phase at lower dopant concentration). It was also found that functionally graded electrolytes can increase conductivity.

SOFC System for Small UAV Applications

- System model established to estimate mass and volume of fully integrated LT-SOFC system for micro UAV.
- Fuel processor and fuel cell stack comparable in weight and volume.
- Results suggest that system (including fuel supply) of < 5 kg and 6 liters can provide 200 W for mission of 20 hrs.



	200 W LT-SOFC System: Propane + Water Tank		200 W LT-SOFC System: Propane + Water Recovery	
	Weight (kg)	Volume (liters)	Weight (kg)	Volume (liters)
Fuel Use/hr	0.040	0.051	0.045	0.056
Water Use/hr	0.170	0.170	0.000	0.000
Balance of Plant	0.603	1.046	0.603	1.046
Fuel Processor	0.895	1.188	0.895	1.188
Water Recovery	0.000	0.000	0.701	0.605
SOFC Stack	1.351	1.101	1.351	1.101
10 hrs. Fuel & Tank	0.465	0.556	0.512	0.611
10 hrs. Water & Tank	1.953	1.865	0.000	0.000
UAV Mission Hrs.	Totals		Totals	
0	2.848	3.335	3.549	3.940
5	4.058	4.545	3.805	4.245
10	5.267	5.631	4.061	4.551
15	6.476	7.008	4.318	4.857
20	7.685	8.385	4.574	5.162

University of Maryland Energy Research Center

Figure 5 – SOFC for small unmanned aerial vehicle applications

For electrolyte layers, results and comparisons associated with samaria-doped ceria (SDC) erbia-stabilized bismuth oxide (ESB) , dysprosium and tungsten stabilized bismuth oxide (DWSB) and other materials were provided. It was stated that 8Dy4WSB gives best conductivity of any stabilized fluorite oxide (~3X that of ESB, 10X that of GDC, and 100X that of yttria-stabilized zirconia YSZ), and suggested that there is room to optimize GDC and ESB thicknesses for power density tradeoffs.

The rare earth elements' considerations for these materials in terms of fraction of total raw material costs per kilowatt are summarized in Figure 6 wherein one finds that nickel in the anode dominates cost considerations.

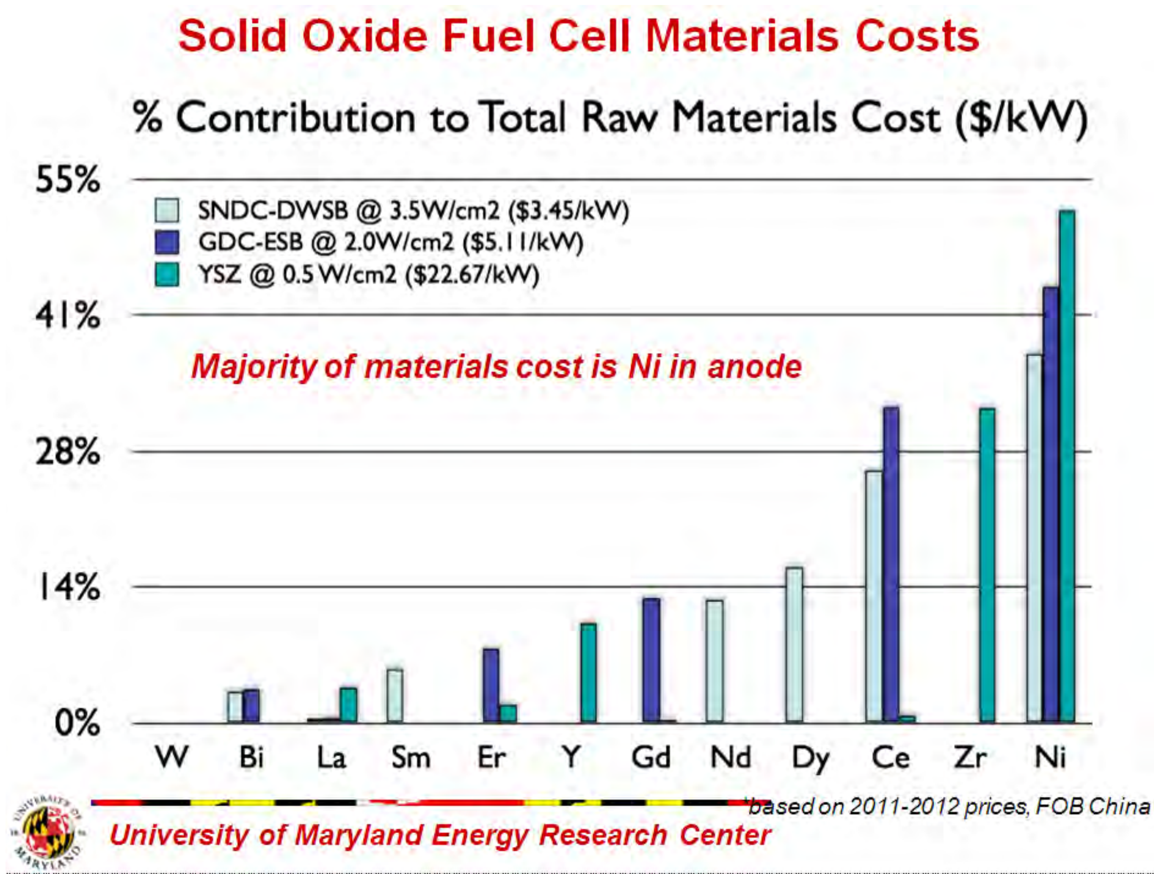


Figure 6 – SOFC relative material costs

Prof. Jackson concluded his keynote remarking that:

- Precious metals content presents a challenge for low-temperature PEM fuel cells and fuel processors/purification for all fuel cell types. However, solid oxide fuel cells will not be limited by rare earth supplies because demands will be small compared to production rates.
- There still is value in reducing expensive rare-earth materials in SOFCs in order to lower costs.
- Utilize double doping both to increase conductivity and reduce fraction of rare earth materials.
- Utilize functionally graded electrolytes to allow flexibility in material choices and enhance electrode performance and durability.
- An increased commercial market is required for DOD to have reasonably cost effective access to fuel cells, though the application considerations are different for DOD.
- There are meaningful tradeoffs to be evaluated between stability, cost, and performance for fuel cell/fuel processing catalysts and various (electrical) energy demanding fixed base and mobility associated military applications (e.g., unmanned vehicles of various types). These all provide motivation for additional investigations, innovations, and developments associated with fuel cells and specialized materials.

7. Keynote Presentation by Dr. Christopher Guzy (Ballard)

Dr. Guzy provided an overview of Ballard Power Systems, Inc., Headquartered in Burnaby, British Columbia, Ballard is a recognized global leader in clean energy Proton Exchange Membrane (PEM) Fuel Cells, with a 2011 revenue of $76M and 440 employees. Ballard works closely with University of Maryland fuel cell researchers as discussed in Prof. Jackson's keynote. Dr. Guzy pointed out that, according to Fuel Cell Today Industry Review 2011, PEMFC technology accounted for 97% of global fuel cell shipments in 2010 and 74% of total megawatts (MWs). PEMFC market components addressed by Ballard are principally backup power, with 1-5kW units utilize for wireless telecom ($1.0B market potential), transit buses using 75kW & 150kW modules ($2.0B potential), material handling 4-20kW modules ($0.8B potential) and distributed power generation with multiple-MW capability (market potential of $3.0B; Germany currently leads in fuel cell use for energy storage for renewable energy).

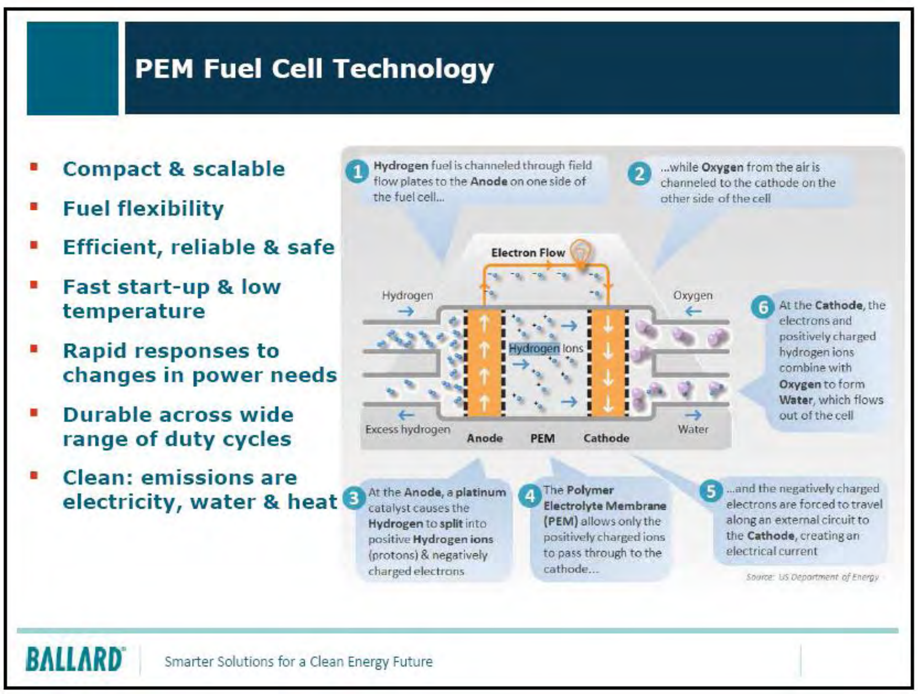


Figure 7 – proton exchange membrane (PEM) fuel cells

Figure 7 was used to highlight the key benefits of PEMFCs, namely compactness, scalability, fuel flexibility, reliability, low temperature operations (compared to SOFC), rapid response to changes in power needs, durability across variety of duty cycles, and clean emissions (electricity, water, and heat).

Dr. Guzy discussed fuel cell applicability to DOD needs in terms of currently available commercial solutions (backup power, distributed stationary power, non-tactical material handling, ground support equipment, non-tactical personnel transport) and developmental programs in research, development and acquisition phases. These include fuel processor design, wearable soldier power, unmanned vehicle power, portable power, and auxiliary power units for land, sea and air platforms. One of the significant differentiators for fuel cells compared to batteries is that fuel cell recharging is significantly faster than battery recharging. Also, a contrasting element of concern in overall supply chain considerations is the wide variety of batteries (at least 500 different types of batteries today, making keeping a robust and fully charged inventory a non-trivial problem)

Regarding fuel cell dependence on REEs, Dr. Guzy reflected that fuel cells have virtually no reliance on rare earth elements, for example molten carbonate does not require REEs, proton exchange membranes rely on non-REE materials, such as platinum as do phosphoric acid fuel cells (concentrated phosphoric acid is used as the electrolyte; they operate at 180 − 200^{o}C). Solid oxide fuel cells use a minimal amount of yttrium in their electrolyte (currently need 21g/kW, so 4GW capability of SOFC systems would require less than 0.5% of current annual yttrium production).

In terms of strategic materials considerations, platinum is the key element of concern for fuel cells. Platinum is primarily mined in South Africa, with large quantities mined in Russia. Current platinum demand driven by vehicle autocatalysts, jewelry, and industrial products, with growing demand for platinum catalysts in fuel cell products predicted. Currently, no shortage is expected as the mining industry will have many years of advance notice and time to ramp up production to meet demand. Additionally, platinum recycling rate is increasing, while the amount of platinum per fuel cell is decreasing. Graphite is 'strategic' for fuel cells since cell bi-polar plates are made from high-purity flake graphite, and there is an overall growing demand from a variety of clean energy technology alternatives, including those associated with lithium ion batteries, and solar cells. Currently, China produces around 75% of the world's graphite. Chinese graphite is considered of relatively low quality, while India and Brazil produce smaller quantities but higher quality graphite. Graphite has been named a 'critical supply material' in both the U.S. and Europe. Metal plates can be alternatives to graphite.

Carbon fiber is also considered strategic. It is used extensively in the aircraft industry, plastics, sporting goods, wind turbines, the automotive market and fuel cells. Carbon fiber is made from Polyacrylonitrile (PAN), a petroleum-based product, through high-temperature heat treatment, in a multi-stage process. Fuel cell carbon fibers are engineered for conductivity, chemical resistance, and fuel cell performance. The trend is for carbon fiber producers to insource PAN manufacturing (Zoltek ,Toray, and Toho). Polymers produced from chemically-stabilized perfluorosulfonic acid for fuel cell membranes may be viewed as strategic. The polymer membranes separate fuel and oxidant in the fuel cell, permitting hydrogen ion transport, while preventing electron conduction, setting up the condition for an external (to the membrane) path for the electron to travel to the cathode. Polymers are widely available so there are no concerns there (Ballard polymers are sourced in the US and Japan). Worth monitoring though, is the fact that due to lesser environmental concerns, China is increasing its chlorinated polymer capacity, while the chlorine plants are not welcome in many US communities.

During the discussion, Dr. Frazier of NAVAIR pointed out that the only significant graphene production in the US is done by 3M, and it has the potential to reduce permeability.

Also noted during the keynote was that all automotive manufacturers have significant investments in fuel cell efforts, and again, national automotive infrastructure is limiting significant introduction of fuel cells in the automotive sector. It is estimated that it will take decades for the automotive component of the economy to fully benefit from fuel cell technologies. Regarding fuel cell manufacturing, Ballard produces 80% of PEM fuel cells, Bloom leads in SOFCs, and UTC Power (a unit of United Technologies) leads in phosphoric acid fuel cells (PAFCs). Although zero emissions argue strongly for fuel cells, the overall economic perspective is that of payback for investment. Currently, fuel cells have a two year or longer payback forecast. It is considered that a 1.5 year payback is the threshold for economic self-interest in fuel cells. Once that is achieved, one may expect significant increase in utilization of fuel cells.

8. Keynote Presentation by Prof. Robert Moore (Virginia Tech)

Prof. Moore presented the keynote talk titled "Tailored Nanostructure of Critical Materials in (PEM) Fuel Cells and Batteries", focusing on nanostructured membrane materials for fuel cells, and on structured electrolyte frameworks and nanostructured "Air Breathing" electrode materials in lithium battery applications.

As described in earlier keynotes, precious metal catalysts in the membrane electrode assemblies (MEAs) are significant cost drivers, as well as potentially critical from the availability standpoint in terms of supplier concentration. Nanoscale engineering and chemistry aided by powerful instrumentation, such as the Argonne National Lab Advanced Photon Source is facilitating use of small-angle X-ray scattering to probe membrane morphology. As benchmarks, Prof. Moore described platinum use as consuming 25 mg/cm^2 in the early days of black electrodes. Today's usage of platinum nanoparticles supported on carbon black utilizing 0.5 mg/cm^2 is more than an order of magnitude better, with Department of Energy's 2015 goal being 0.2 mg/cm^2. Prof. Moore described how thermal morphological annealing is being used to order the ionic domains, resulting in improved PEMFC efficiencies.

Lithium-Ion (Li-Ion) batteries have gained acceptance and increased use due to their high energy density profiles coupled with their recharge and size specification flexibility. Propylene carbonate, ethylene carbonate and dimethyl carbonate are some of the more common polar organic solvents for electrolytes. Now, progress is being made in developing insoluble, mechanically-robust, polymer-gel electrolytes, using electrospinning with cross-linked poly(ethylene oxide) (PEO) mats . Figure 8 provides an illustration of the cross-linking process.

Prof. Moore described the new and promising area of nanostructured electrodes. Illustration of the concept is provided in Figure 9. The practical specific energy achievable with "Air-Breathing" nanostructured Li-Air batteries is significantly higher than Lead/acid, NiMH, Li-Ion, and other batteries (nearly 4000 Watthour/kg being practical and large specific energy densities theoretically achievable). Also shown were micrographs of hollow carbon fibers with nanopores and catalyst nanoparticles (MnO). The keynote illustrated the significant progress being achieved in design, engineering and fabrication of tailored nanostructured materials for use in fuel cells and batteries. Thus, while there are various availability concerns regarding precious metals and rare earth metals in battery and fuel cell applications, the emerging ability to increasingly better design and control matter on the nanoscale that leads to promising alternative materials, mitigates these concerns for batteries and fuel cells.

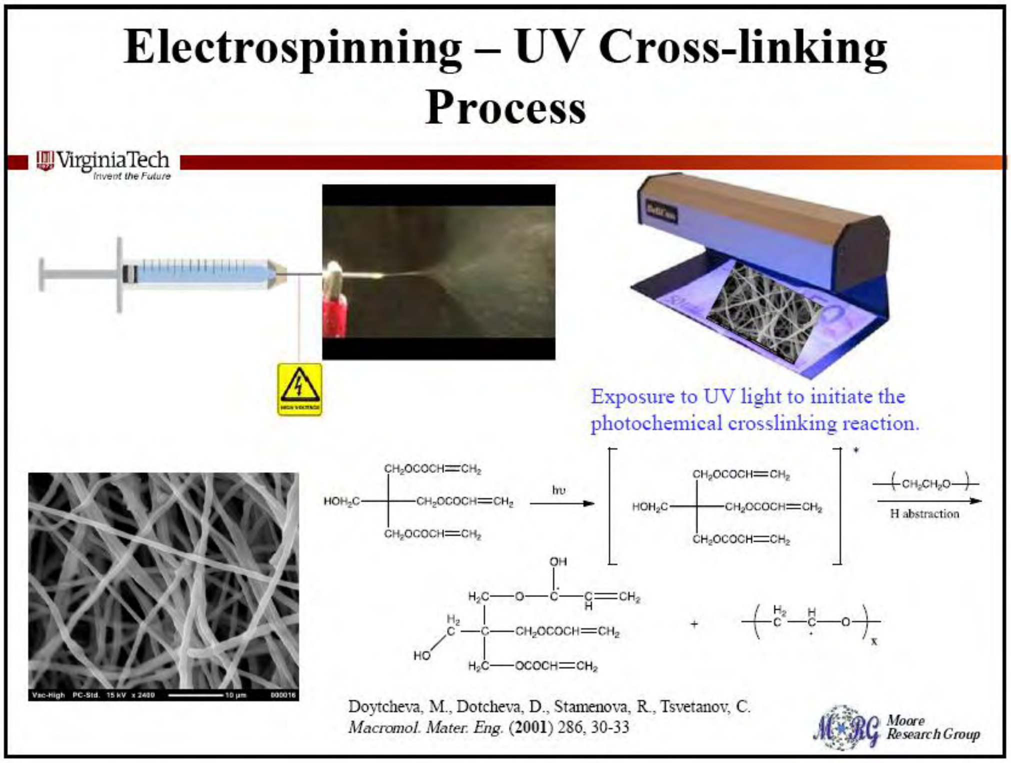


Figure 8 - Electrospinning UV light Cross-linking process

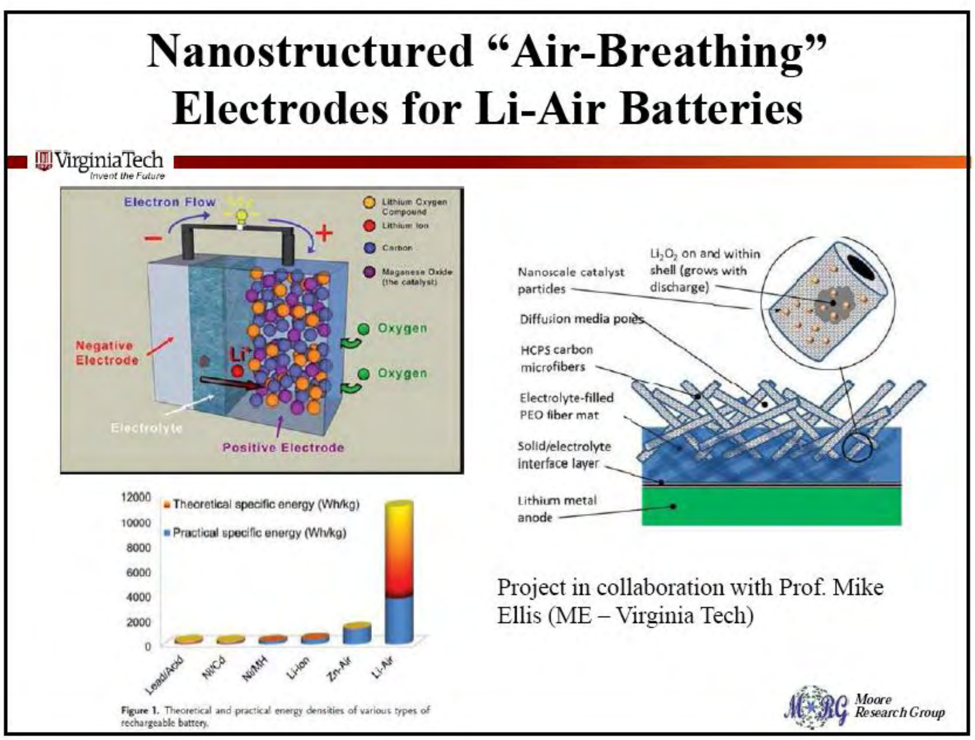


Figure 9 – Nanostructured electrodes for Li-Air batteries

9. Keynote Presentation by Dr. Kamen Nechev (Saft Groupe SA)

Dr. Nechev, Chief Technology Officer at Saft Groupe SA in Cockeysville, Md., a leading specialty and industrial battery providers delivered the *Materials for Batteries: Industry Prospective* Keynote address. SAFT specializes in industrial standby, soldier communications, aviation, grid stabilization/smart grid, and other specialty batteries. SAFT SA had 2011 sales of approximately $843M. Its US space and defense related products principally support vehicle related programs (NLOS-C, RSTV, HMMV, and GCV), aircraft (JSF F-35), weapon-related lasers and microwave technologies, unmanned aerial and underwater vehicles and satellites and launchers. SAFT is the largest supplier of communications batteries for the US Army, and a leading supplier of batteries for electrical grid smart meters. It has provided the largest municipal backup battery (Fairbanks, Alaska). Figure 10 depicts some of the extreme performance requirements in defense and space applications.

Performance Requirements Driving Materials need

- Defense applications always have very demanding performance requirements. These requirements could be met with:
  - Novel materials
  - Novel processes
  - Novel electrochemical concepts

Application	Performance Requirements	Materials Development
Ground Vehicles	Low Temp Power (-40°C), Regenerative power, Pulse Power, Long cycle life	Improved anode materials, novel processes
Military Aircraft	Low Temp Power (-40°C), Regenerative power, Pulse Power, Long cycle life	Improved anode materials, novel processes
Submersibles	Very High Energy, Uncompromised Safety, long life	High energy materials, non-flammable electrolytes
Weapons	Very High Power (>25kW/kg)	High power cathode and anode, novel process
Space	High Energy combined with Very Long Cycle and Calendar Life	High energy stable cathodes and anodes

Figure 10 – Saft Groupe performance requirements driving specialty batteries' material design

Defense requirements, such as the Joint Strike Fighter (JSF) need for an emergency battery that must respond within 100 milliseconds to demand fighter's auxiliary power unit to restart the engines at-40^{o}C provides a unique perspective that is just not routinely met by everyday battery cells. Likewise, batteries to support megawatt laser operations provide another extreme set of requirements..

Advanced commercial demands are changing the battery landscape. For example, lithium nickel manganese cobalt (NMC) batteries look to be significant in the computer market and lithium (NCA) nickel cobalt aluminum batteries are making a comeback (Tesla car). Lithium metal phosphate batteries are also of great interest due to improved safety and flammability considerations.

Drivers in battery design, beyond energy density and recharging cycles, include battery shelf life, lifetime and aging considerations and of course safety and flammability considerations (a major issue with submarine and underwater systems).

Dr. Nechev's perspectives regarding availability of a robust and capable materials base for defense applications in the US is that there must be a robust capable research and development (R&D) base in the US, and a logical and functioning connection between R&D base and the real Industry. While start-ups are important, the real challenge is in the scale-up, and this is where start-ups encounter serious challenges. There must be real incentives for industry to develop products for defense applications. Experience shows that defense programs have unpredictable futures with idealized requirements whereas corporate decisions are driven by profits, not ideals. Also, corporate considerations seek synergies of investments with potential for large volume applications. The US corporate materials base is in reasonable shape. U.S. corporate domestic production plans include TODA America and BASF producing cathode materials, Conoco/Phillips is producing anode materials, BASF (Novolyte) and Techno Semichem producing electrolyte, and Celgard and Entek producing separator materials.

What is missing is abundant scale up knowledge, namely the understanding of the difficulties to take a material from the lab to the volume production. These include understanding of the:

- issues in large scale equipment (materials compatibility, impact of size on process, etc.),
- batch (lab) versus continuous (industrial) process,
- cost and ownership (who does what),
- scale up process itself, and
- materials to market.

Some recommendations that emerged from Dr. Nechev's keynote suggest that DOE's battery agenda could be improved by identifying and using synergistic needs between different government branches beyond targeting hybrid and electric vehicles energy storage for the grid. Also, while the academic grant funding and small business oriented (SBIR/STTR) funding mechanisms are well understood and utilized, serious industry funding for research and development does not appear clear.

Regarding Lithium-Ion technologies, SAFT works with universities and small businesses to:

- guide and help develop new materials and concepts,
- test in industrial environment early stage development,
- integrate the new materials into industrial battery designs, and
- provide prototypes to Defense customers.

Regarding materials synthesis, SAFT views itself as a bridge between small business entities and large materials synthesis companies such as BASF and 3M. Figure 11 depicts a way of looking at the roles. Small companies have great fear of being outmaneuvered and outsmarted on the business and intellectual property (IP) front, as well as generally lack investment capital for 'real operations'.

Figure 11 – SAFT as a bridge between small companies and large industrial firms.

The large industrial companies that can inexpensively produce materials, like 3M and BASF, and that have the industrial and chemical engineers for large operations, do not want to get into low volume production. One needs to develop an appreciation that going from the academic /small business scale of 5 gram of a unique material, to a limited production of 100 kilogram, and then to a 100 ton production scale is a 'huge process'. There are many small labs with lots of good ideas. How to successfully scale up is the real issue.

The 'bridge' role is one that NASA had hired SAFT to execute in the past. Dr. Nechev contrasted the U.S. approach of 'being out on your own' once a small company is beyond the SBIR/STTR phase, and the Japanese government approach where Japan subsidized the Toyota Prius until it became economically self-sustaining. Dr. Nechev also discussed SAFT's relationship with University of Maryland and the Army Research Lab (ARL). Since university and DOD labs do not compete in the commercial marketplace, investigators can work with SAFT in SAFT's labs. It is valuable to students, interns, young faculty to gain operational insight and experience in day-to-day operations 'on the floor'. This is an experience currently lacking with many U.S. engineers. This model can be used by other companies and organizations to improve US competitiveness and readiness.

As final notes, Dr. Nechev stated that lithium is not the cost driver. From his perspective "it's all about the polymers" and connecting the technology base with the R&D, and industry and at the same time providing incentives for industry to develop DOD products. Figure 12 depicts a prototypical example of a decade of development of a practical high power lithium ion battery for DOD applications at SAFT.

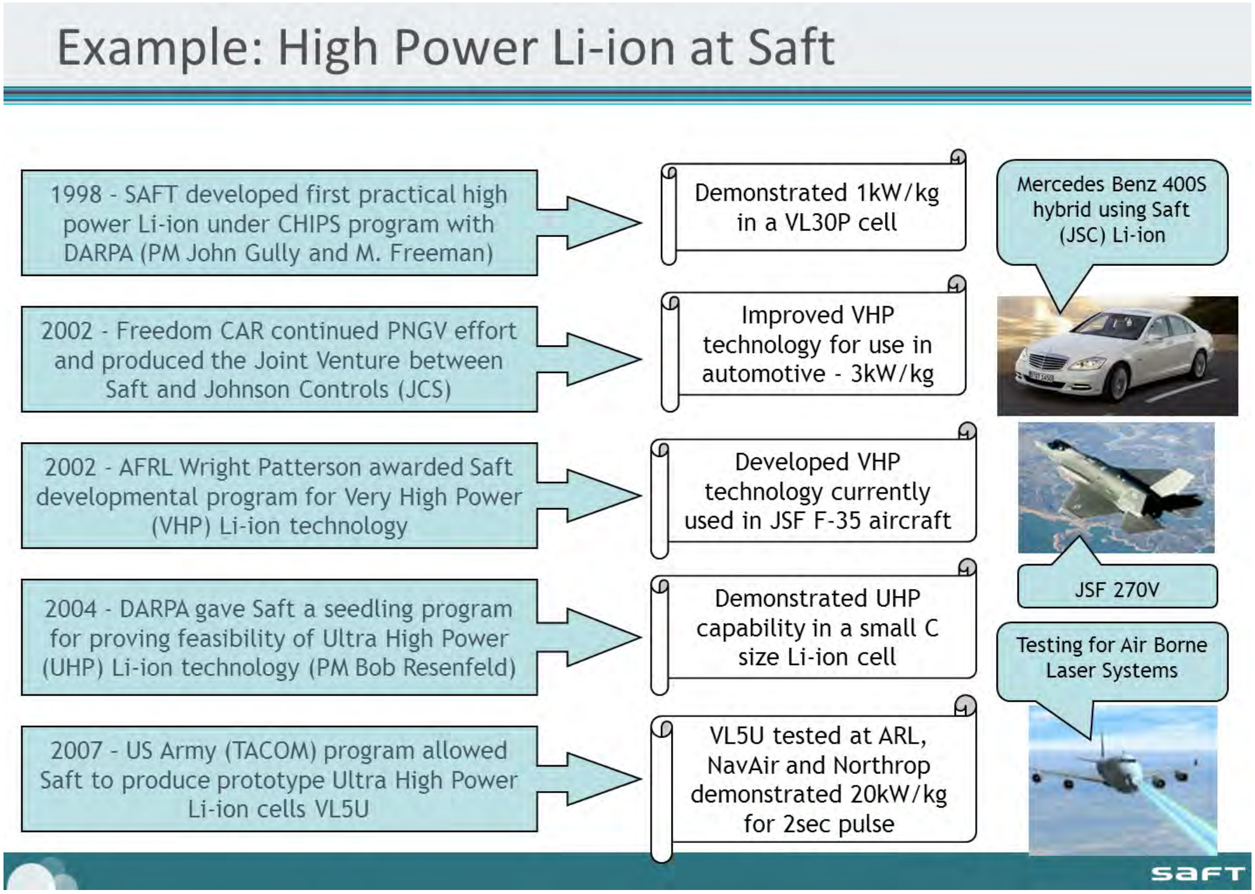


Figure 12 - Development of a practical high power Lithium Ion battery for DOD applications at SAFT

10. Rare Earth Elements Panel

The afternoon sessions were organized into interactive panels on the theme areas of rare earth elements, fuel cells, batteries, and DOD users. The approach was for the panelists to provide some framing remarks and perspectives, and then have increased dialog via questions from all symposium participants. The rare earths elements panel consisted of, in alphabetical order, Mr. David Cammarota (OSD), Mr. Peter Dent (Electron Energy Corporation), Mr. Dylan Hazelwood (University of Maryland, CECD), and Mr. Steve Moffitt (Capstone National Partners). Mr. Dent, of Electron Energy Corporation (one of the earliest RE magnet producers, and one of two RE magnet producers in the US) provided a detailed presentation of rare earth elements' contribution and importance in permanent magnets. Due to the breadth of the discussion, this particular panel component is described in more extensive details than others.

a. Rare Earth Magnet Technology Overview (Mr. Peter Dent)

Mr. Dent explained the REEs' particular attractiveness in permanent magnet (PM) design as being due to unfilled "3d" and "4f" electron orbital shell combination. This results in materials with very high anisotropy, allowing easy magnetization in one direction, difficult to demagnetize in others direction, and providing designers materials with good magnetic properties under a broad range of temperatures. As a result of increased automotive uses, and increasing miniaturization of magnets, more applications come into being, feeding a cycle of increased use (smaller magnets make smaller less costly products; less costly products increase market share and use). Also as the automotive and other industries move into the electric car and "more electric" applications, more magnets will be needed. The principal REEs used in PM design are the lighter neodymium (Nd) and the heavier dysprosium (Dy).

The economics of REE currently mandates that industrial organizations must extract material at point in supply chain where profitable in a "Mine to Market" stream. For the Nd15Fe77B8 magnet powder (NdFeB), the companies that are doing so are Molycorp, NdFeB JV, Neo Materials, Lynas-Siemens JV for NdFeB, and Great Western Minerals Group (GWMG) Less Common Metals Limited (LCM). Figure 13 depicts a notionalized process for magnet manufacture.

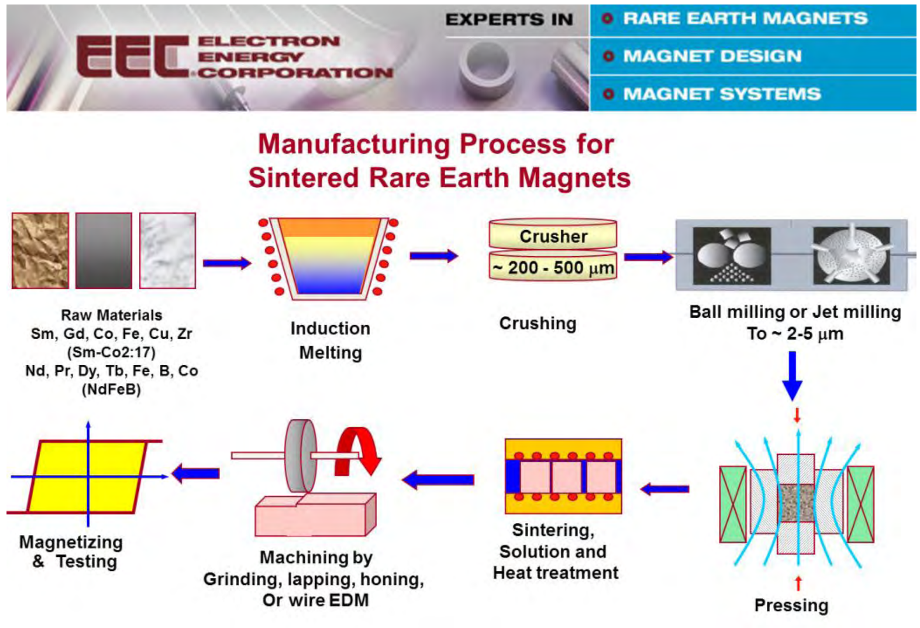


Figure 13 – Manufacturing process for sintered rare earth magnets

Mr. Dent presented charts and statistics reaffirming the known issues including those of Chinese dominance in REE mining and supply, pricing, differential prices in the US and Chinese markets. The permanent magnet related REEs, one now tracks carefully are dysprosium (Dy), terbium (Tb), neodymium (Nd), samarium (Sm), and gadolinium (Gd). Dy, Tb and, Nd, are considered critical by the U. S. Department of Energy and by the European Union. Dy availability is expected to be in a shortfall situation. At the same time, there are 2009 reports that SmO and CeO are in such excess in China, that some of it is dumped as waste. Responses to these supply condition vary, some practice demand destruction (mitigation, replacements - Toyota, Honda), some companies are looking to add capacity inside China due to REE ease of access (Intermatix Phosphors, Showa Denko, Santoku).

However, Mr. Dent pointed out that over the past 270 years, there has been steady and sustained progress in increasing magnet effectiveness. This is displayed In Figure 14.

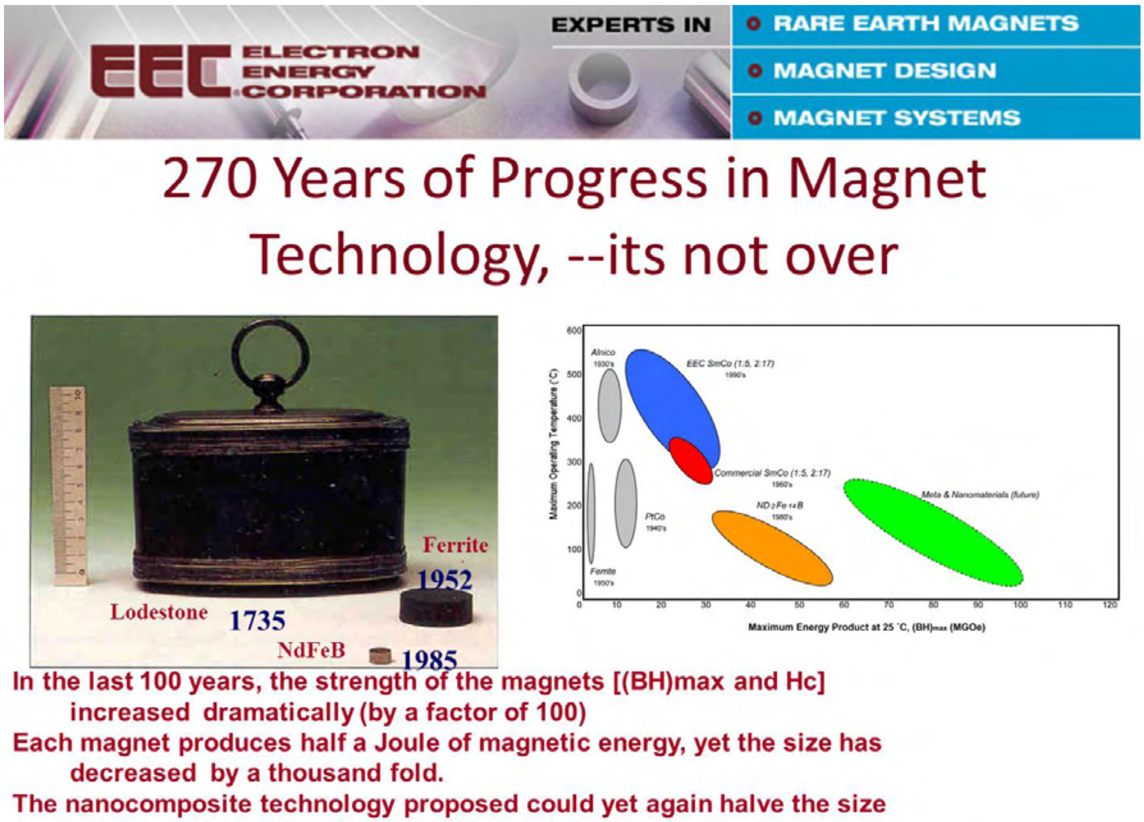


Figure 14 – Progress in magnet technology

Along these lines, Mr. Dent described some promising mitigation approaches. For example, a University of Delaware-lead team is exploring magnetic exchange hardening of soft magnetic phases (Fe or Co) by hard magnetic phase (NdFeB or SmCo), with the goal of doubling (BH)max in nanocomposite magnets of Nd-Fe-B or Sm-Co, reducing REE use, and increasing energy density (funded by ARPA-E round 1 at $4.6M). Another example is Argonne National Lab's nanocomposite exchange spring magnet project exploring combining a hard magnetic outer shell with a soft magnetic inner core to increase the energy product and operating temperature. The goal of this project is to demonstrate a new type of magnets in a prototype electric motors and generators (ARPA-E round 4 "REACT" Funding $1.7M). University of Maryland (Takeuchi) – PNNL (Jun) team proposes to develop a manganese based nanocomposite magnet alternative to rare-earth based magnets, to exceed the performance of today's most powerful commercial magnets at temperature higher than 200°C. The intended goal is to have reduced wind turbines and electric vehicles costs (ARPA-E Round 4 $1.62M)

Among alternative considerations are NdFeB vs. SmCo, Induction vs. PM motor/generators, revisiting lighting choices - fluorescent vs. LED (compact fluorescent lamp (CFL)/linear fluorescent lamp (LFL) reduce 5 REE usage in phosphors), reducing/eliminating cerium in steel alloys. Recycling rare earth permanent magnets deserves more attention. This has not been an area of investigation as challenges to PM recycling are significant. Brittle intermetallics imbedded in assemblies in epoxies – are very difficult to physically remove, as are organics from machining, coatings and epoxies. The chemical separation issues are unresolved, the return on Investment unknown, as are the long term prices of REEs recovered. The collection is difficult due to hundreds of various applications and many more collection points. This is where government policy choices (recycling mandates) in the face of HREE shortages should be explored. Mr. Dent also presented some thoughts about other groups of materials that may also face supply availability issues. Mr. Dent concluded his prepared remarks by offering the following suggestions:

- Establish a baseline – facilitating studies by DOE, GAO, DOD,
- Interagency White House OSTP led coordination,
- Ensure fair trade – USTR, EU, Japanese joint request for WTO consultations with China (REE, W & Mo),
- DOE led support for technology development (ARPA-E, Critical Materials Hub),
- Innovation, training and workforce development,
- Government inventories – DLA procurements, and
- Defense critical components support -Defense Production Act programs.

b. Additional REE Panel Comments

Mr. Cammarota followed up on the subject of recycling, asking about the scope of possibilities that are technically feasible (in collecting, processing, etc.). As a reference point he mentioned that, in 2010 1.1 million pounds of fluorescent bulbs were collected by the Department for recovery of the contained mercury, a hazardous material. Leaving aside the larger economy, and concentrating on the US government and DOD activities, are the aggregate amounts of items collected in sufficient amounts to create the economies of scale for recycling (e.g. of magnets from hard drives). It may be beneficial to conduct a waste stream analysis of batteries, bulbs, magnets, and so on disposed of by US government and DOD. Mr. Cammarota also clarified additional points regarding the process to add materials to the strategic stockpile list. DOD provides an annual materials plan to Congress recommending maximum levels of sales/acquisitions for stockpile materials[6]. Mr. Cammarota explained that there's a transaction fund in the program that is used to operate Defense Logistics Agency stockpile operations.

[6] See for example, DOD - *Strategic and Critical Materials Operations Report to Congress; Operations under the Strategic and Critical Materials Stock Piling Act during the Period October 2007 through September 2008,* <https://www.dnsc.dla.mil/Uploads/Materials/esolomon_5-21-2009_13-29-4_2008OpsReport.pdf> where the 2008 process is explained as "The Annual Materials Plan (AMP) lists the maximum quantity of each commodity that may be sold or bought by the Department of Defense (DoD) in a given fiscal year. Before any materials may be bought or sold, Congress must enact specific enabling legislation. After receiving congressional authority, DoD develops the AMP, which is submitted to Congress by February 15th of each year. Prior to submission, the AMP is coordinated with the Market Impact Committee, an interagency committee that advises DoD on the projected

Dr. Frazier (NAVAIR) commented that rhenium is currently being recycled. He also commented that several natural questions suggest themselves, namely:

- Are there some REE depend parts that can be re-used on a "same-for-same" basis?
- Is there enough science to definitively determine if some materials can or cannot be recycled?
- Should a national 'disposed REE parts' policy be considered so we can store REE containing parts until a viable REE separating /recycling technology is developed?

domestic and foreign economic effects of the proposed Stockpile transactions. The AMP is effective on the first day of the fiscal year. If DoD proposes significant changes to the AMP during the fiscal year, a revised AMP is submitted to Congress. The revisions become effective 45 calendar days after their submission." A recent Federal Register Call is located at , https://www.federalregister.gov/articles/2011/09/21/2011-24172/national-defense-stockpile-market-impact-committee-request-for-public-comments-on-the-potential> stating "**…** The purpose of this notice is to advise the public that the National Defense Stockpile Market Impact Committee (MIC), co-chaired by the Departments of Commerce and State, is seeking public comments on the potential market impact of the proposed disposal levels of materials for the Fiscal Year (FY) 2013 Annual Materials Plan. The role of the MIC is to advise the National Defense Stockpile Manager on the projected domestic and foreign economic effects of all acquisitions and disposals of materials from the stockpile…."

11. Fuel Cell Panel

The fuel cell panel consisted of, in alphabetical order, Dr. Chris Guzy (Ballard), Prof. Gregory Jackson (U. Maryland), Dr. Charles Rong (Army Research Lab), and Prof. Eric Wachsman (University of Maryland). The panel extended some of the earlier discussions and clarified some points. One question that arose was that of replacing platinum and platinum alloys. Dr. Guzy remarked that he is observing a marked trend in the use of platinum, and that its use in fuel cells is likely to decline by an order of magnitude in the next 5-10 years. The technical challenge is that 'there's nothing like platinum' when it comes to its having the highest stability simultaneously as catalyst and an electron conductor. It is possible to use iron alloys in alkaline fuel cells, the technical challenge there is the effect of CO. CO can stop the functioning of fuel cells, thus being a technology challenge. In this regard as well, Dr. Frazier remarked that DOD is driven by cost and schedule milestones, which can be adjusted. If one were to implement HAZMAT like importance and policies to incentivize recycling, much can be done. Prof. Jackson agreed, saying we are not making it easy to recycle. Dr. Nechev pointed out that in the 'battery world', the US Government provides the silver to use in silver/zinc batteries, while maintaining ownership of the silver. This is true of ICBMS as well, and in the case of specialty steel for submarines, the government controls the specialty steels.

The point that one can create thinner electrolytes that use less REE in fuel cells can certainly help. Bloom does in fact do so. Prof. Wachsman reiterated the potential for dual doped materials to drive REE use down. Dr. Guzy reflected that there is significant potential for platinum recycling. He identified one of the sources of the increased platinum demand as Europe's 2005-2007 transition to increased use of diesel engines which created an unexpected demand on platinum driving prices up. It was his opinion that mines can ramp up production, and that the fluctuation of styles and usage of Platinum in jewelry can have an impact as well.

Another point that was brought up was that it is easier to recycle 'surface applied' substances, as occuring in catalysts, compared to separating metal alloys into constituents. Participants agreed that creating substantive goals, e.g. 1000 hours endurance for fuel cells and batteries would help create a large market, and in turn those would create momentum for lowering prices due to economies of scale and competition. Another topic that came up was the question of viability of renting/leasing out fuel cells and batteries as means of accelerating larger scale FC and battery use. Dr. Nechev commented that 'renting' does not look good on P&L (Profit and Loss) reports for companies. Dr. Doerry (NAVSEA) commented that one needs more stability and understanding of performance and use before setting rates in leasing.

12. Batteries Panel

The batteries panel consisted of, in alphabetical order, Mr. Kevin Cook (Naval Sea Systems Command), Dr. Karen Long (NSWC Dahlgren Division), Prof. Roger Moore (Virginia Tech) and, Dr. Kamen Nechev (SAFT SA).

The panel reviewed and clarified some of the earlier keynote points. It was agreed that despite its prominence, lithium availability is *not* a concern. NiMH is losing market share due to its being both more expensive and providing less performance. It is essentially 'going away'; NiMH is not manufactured in the US and is mostly manufactured in Japan. Saft can be said to 'be ahead' by having never been involved in NiMH. Mr. Cook reflected that for Navy/DOD interests, there is a desire to be more in control as far as batteries go, especially regarding reliability, and it is desirable that batteries utilized in DOD not be produced overseas due to the significant reliance on batteries. In this sense, batteries can be considered 'strategic items'. Of prime/critical importance to the Navy, is the safety of batteries in undersea applications. This safety requirement sets unique requirements. Again stated, was that REEs do not play a prominent role in the battery arena.

It was remarked that Japan is doing a lot more in the "process" of design and engineering of batteries while the US is not. This allows Japanese manufacturers to better tailor batteries to specific needs. Technical aspects that merit attention are iron/phosphate chemistry, and the ability to detect incipient 'shorts' in batteries. It was also remarked that most work is driven by the Department of Energy and not the Department of Defense. The principal motivator in battery technology now is extending electric vehicle driving range. Also mentioned again was the coming (2015) requirement to incorporate start/stop fuel usage in calculating miles per gallon (mpg) in car performance. The mpg metrics will incentivize hybrids and battery powered cars. The next main challenge is to have lower cost batteries (e.g., Li-Ion) with ten-year warranties. However, in looking at the project deliverable timescale, DOE is looks at longer timeframes than DOD. DOD is significantly more near term focused. It is of interest to note that it was really DARPA that started the Li-Ion 'push' that migrated to US Army applications, and then to DOE and the automotive markets.

Dr. Nechev noted that there is room for other battery related advances, namely in power management, and charging, for instance conductive charging through the hull of platforms or charging a UAV via lasers.

13. DOD Users Panel

The DOD users panel consisted of, in alphabetical order, Dr. Norbert Doerry (Naval Sea Systems Command), Mr. William Mick (representing Naval Sea Systems Command) , and Dr. Millard Firebaugh – (Minta Martin Professor of Practice University of Maryland, and RADM (RET) US Navy).

The consensus of the panel was that organizations like NAVSEA (Naval Sea Systems Command) and its components do not see the REE/strategic materials issue every day. There is very little that NAVSEA can do at the aggregate level of the REE supply issues. What an organization like NAVSEA sees are issues at the component and system level, and if there are issues at those levels, then NAVSEA can explore ways to engineer around the component issue. It was observed that in acquisition programs, one looks at the *risk* that component or system suppliers would not be able to design or deliver the needed components. For example, what amounted to 'regulated shortages' were created as a result of environmental concerns with Halon and Freon. The mitigation approach was to first create a stockpile for the known materials, and then engineer around these materials.

Essentially, the program managers 'transfer' the problems to the suppliers, and the suppliers then work to figure out solutions. There may be room to develop 'roadmaps' to identify compatibilities and technologies, but not specific components and materials. Dr. Firebaugh also mentioned the 'Rickover Policy' at the time, which was two have two sources for everything that concerned critical technologies (in the nuclear navy), this also allowed for cost reduction. Eventually as programs declined and the nation arrived at one supplier situation (e.g., for nuclear submarines), the approach was to develop a very rigorous procedure well ahead of the occurrence. It may be appropriate to visit this approach and explore if and where this makes sense in the strategic and critical materials arena.

Mr. Dent brought up the DOE Critical Materials Hub approach, and remarked that the substitution time for a new material appears to be 20-25 years.

In concluding, it was observed that while we frame many discussions on the 'free market' model, China is not a free market, Japan and Korea are stockpiling REEs, and much of the supply issue is a matter of policy and not technology.

14. Post Symposium Comments

After the conclusion of the symposium some participants provided additional perspectives and points for consideration.

Dr. Firebaugh raised the following points:

1. As a matter of national security, we would be remiss not to have a process for determining that we were in serious danger of losing access to a material that we can see is vital to critical defense technology that we will be depending on for the foreseeable future.

2. If we put such a process in place on a more focused defense wide basis than the somewhat hit or miss processes that are presently in place in some DOD organizations, it will not be meaningful unless there is a specific strategy to address the pending shortfall.

3. Implementing such a strategy means funding some way of either stockpiling the material or engineering around the material or both.

4. Money is scarce and the notion that there will be funds for this kind of activity will generate a lot of perceived needs.

5. The administration of the funds will have to be resolute in only showing interest in materials for which the threatened shortfall is clear and the importance of the technology that relies on the material is of surpassing and enduring significance.

6. Once the material shortfall is identified and remediation is funded, the funding must be continued until the crisis is clearly resolved. This kind of singleness of purpose will be hard to sustain. For example, if the rare earth dysprosium is identified and the only source for the material in useful quantities is China and DOD puts in place a program to engineer systems so that dysprosium is no longer needed, an alert Chinese government will drop the price so that it looks stupid to fund the development of a work around. The system will have to stand tall in the face of that kind of market manipulation and continue the funding until the job is done.

7. These kinds of efforts are hard to sustain and will be impossible to manage effectively if the criteria for getting on the list is anything less than daunting.

8. There will have to be a lead agency selected to manage the strategic material work around on a material by material basis. The funding should come from some OSD line, but the work needs to be done by a DOD agent who has the most compelling grip on the technology involved.

9. If such a list is created and ends up having more than four or five materials to deal with, it will become unmanageable.

Dr. Charles Rong provided the following comments:

1. The Federal government needs a special committee/task force to coordinate the efforts on critical and strategic materials in R&D, domestic production, international trade. It will draw expertise from academia, industry and, government for in depth discussions and provide strategy and recommendations to policy makers or to the executive branch of the government.

2. The nation needs a robust program to recycle all the used mechanical, electronic, and chemical processing components that contain critical and strategic materials, no matter how high or how low of their content. At a minimum, this can serve as a means for temporary storage until efficient recovery processes are fully developed. The bottom line is to avoid these valuable critical and strategic materials ending up in landfills.

3. Although research and development for alternatives of the critical and strategic materials is desired as a long term objective, practically and equally importantly, focused R&D effort in advanced mining and extraction technology of the rare earth metals in the United States, as well as advanced recovery technology for the critical and strategic materials from used and recycled parts/components, will probably generate economic and strategic benefits relatively sooner.

4. The federal government should help accelerate clean energy technology penetration to the market. Placing Ballard PEM based fuel cell systems for distributed power generation in locations such as Wal-Mart stores and telecommunication towers would represent an opportunity with high potential for success for the government to facilitate further deployment of fuel cell technology in the market place.
5. Given the increasingly intensive competition for all natural resources, which is the result of globalization and technological advancement, the critical and strategic materials will remain as one of the issues of national strategic importance for the foreseeable future. In today's increasingly complex and more challenging world, rapid and successful development of clean energy technology, which in part relies on critical and strategic materials, will be one of the technology differentiators that determine the world leadership for the 21st century.

15. Conclusions and Recommendations

The symposium allowed many strategic and rare earth element related issues, concerns, and possibilities to be discussed in the context of DOD needs and applications. Attention was placed on real world cutting edge fuel cell and battery technologies, and their possible dependence on strategic and rare earth materials.   What became abundantly clear is that:

a. The overall economy is the driver in REE and strategic material utilization, not DOD, (the automotive and electric grid energy generation and storage will dominate the economics and materials availability considerations for batteries, fuel cells, and permanent magnet motors).

b. The strategic and critical elements of yesterday may not be strategic and critical today, and what is strategic and critical today may not be tomorrow, and we need to keep an eye out for what may strategic and critical be tomorrow.

c. Industrial initiatives like Molycorp's Project Phoenix at Mountain Pass with production of 40,000 tons per day at conclusion of phase 2 (mid 2013) may well change the REE dynamics.

d. Next generation enhancements to magnet technologies with greater yields using smaller quantities of dysprosium, and greater magnet production yields are coming.

e. Solid Oxide Fuel Cell (SOFC) and Proton Exchange Membrane Fuel Cell (PEMFC) have a growing role in the economy.

f. Fuel cells or batteries do not consume large amounts of REEs, however they do consume other materials (for example precious metals such as platinum and palladium as catalysts); fuel processing catalysts and membrane compositions that use precious metals and certain polymers and graphite may be viewed as strategic.

g. Legislation currently on the books (such as incorporating the stop/go conditions for computing miles/gallon metrics in 2015, will likely accelerate demand for hybrids and electric vehicles, increasingly driving up need for strategic materials and precious metals).

h. There are viable and promising research avenues to improving fuel cells and batteries as well as mitigating supply concerns (e.g. double doping leading to better conductors, functionally graded electrolytes that increase conductivity, platinum recycling, thermal morphological annealing to order the ionic domains results in improved PEMFC efficiencies, nanostructured materials for use in fuel cells and batteries).

i. It is valuable to students, interns, young faculty to gain operational insight and experience in day-to-day operations ‘on the floor’. This is an experience currently lacking with many U.S. engineers.

Recommendations that flow from symposium proceedings and the above conclusions include:

a. Institutionalize a government-wide, interagency effort to continuously focus on the importance of materials to future economic prosperity and national security including assessing their supply chains, and ensuring their availability.

b. Maintain awareness of potential shortfalls and mitigation approaches for elements such as dysprosium (but note that promising mitigation approaches for example manganese based nanocomposite magnet alternatives are possible, as are significantly reduced quantities needed when using very high purity compounds, and use of miniaturized magnets).

c. Support both robust capable research and development (R&D) base in the US, and a logical and functioning connection between R&D base and the real industry with attention to scale up (a stage where small businesses and start-ups encounter serious challenges.

d. Establish a serious effort in the policy aspects as well as the science and engineering of recycling strategic materials and rare earth element based alloys (e.g., recycling rare earths permanent magnets (science definitively determine if some materials can or cannot be recycled), consideration of a national ‘disposed REE parts’ policy to store REE containing parts until a viable REE separating recycling technology is developed).

e. Take ‘there’s nothing like platinum’ saying seriously (highest stability simultaneously as catalyst and an electron conductor), and consider a program to design platinum grade or better materials without precious metals or REEs.

f. Consider the merit of US government ownership and ‘no cost rental’ of unique precious metals and REEs, as the government now does with silver (used in batteries), and specialty steels.

g. Establish significant ‘challenge benchmarks/goals’ such as 1000 hour-endurance for fuel cells and batteries.

h. Be mindful of establishing perceived but nonexistent needs.

i. Consider developing government and industry consolidated roadmaps providing visibility of strategic and critical materials availability, expected needs, and key perceived mitigation challenges and initiatives underway.

APPENDICES

A. H. R. 1540 - NATIONAL DEFENSE AUTHORIZATION ACT FOR FISCAL YEAR 2012 - SECTION 853

SEC. 853. ASSESSMENT OF FEASABILITY AND ADVISABILITY OF ESTABLISHMENT OF RARE EARTH MATERIAL INVENTORY.

(a) REQUIREMENT.—Not later than 180 days after the date of the enactment of this Act, the Administrator of the Defense Logistics Agency Strategic Materials shall submit to the Secretary of Defense an assessment of the feasibility and advisability of establishing an inventory of rare earth materials necessary to ensure the long-term availability of such rare earth materials. The assessment shall—
(1) identify and describe the steps necessary to create an inventory of rare earth materials, including oxides, metals, alloys, and magnets, to support national defense requirements and ensure reliable sources of such materials for defense purposes;
(2) provide a detailed cost-benefit analysis of creating such an inventory in accordance with Office of Management and Budget Circular A–94;
(3) provide an analysis of the potential market effects, including effects on the pricing and commercial availability of such rare earth materials, associated with creating such an inventory;
(4) identify and describe the mechanisms available to the Administrator to make such an inventory accessible, including by purchase, to entities requiring such rare earth materials to support national defense requirements, including producers of end items containing rare earth materials;
(5) provide a detailed explanation of the ability of the Administrator to authorize the sale of excess materials to support a Rare Earth Material Stockpile Inventory Program;
(6) analyze any potential requirements to amend or revise the Defense Logistics Agency Strategic Materials Annual Material Plan for Fiscal Year 2012 and subsequent years to reflect an inventory of rare earth materials to support national defense requirements;
(7) identify and describe the steps necessary to develop or maintain a competitive, multi-source supply-chain to avoid reliance on a single source of supply;
(8) identify and describe supply sources considered by the Administrator to be reliable, including an analysis of the capabilities of such sources to produce such materials in forms required for military applications in the next five years, as well as the security of upstream supply for these sources of material; and
(9) include such other considerations and recommendations as necessary to support the establishment of such inventory.
(b) FINDINGS AND RECOMMENDATIONS.—
(1) IN GENERAL.—Not later than 90 days after the date on which the assessment is submitted under subsection (a),
the Secretary of Defense shall submit to the congressional defense committees—
(A) the findings and recommendations from the assessment required under subsection (a);
(B) a description of any actions the Secretary intends to take regarding the plans, strategies, policies, regulations, or resourcing of the Department of Defense as a result of the findings and ecommendations from such assessment; and

(C) any recommendations for legislative or regulatory changes needed to ensure the long-term availability of such rare earth materials.
(c) DEFINITIONS.—In this section:
(1) The term ‘‘rare earth’’ means any of the following chemical elements in any of their physical forms or chemical combinations and alloys:
(A) Scandium.
(B) Yttrium.
(C) Lanthanum.
(D) Cerium.
(E) Praseodymium.
(F) Neodymium.
(G) Promethium.
(H) Samarium.
(I) Europium.
(J) Gadolinium.
(K) Terbium.
(L) Dysprosium.
(M) Holmium.
(N) Erbium.
(O) Thulium.
(P) Ytterbium.
(Q) Lutetium.
(2) The term ‘‘capability’’ means the required facilities, manpower, technological knowledge, and intellectual property necessary for the efficient and effective production of rare earth materials.

B. H.R. 4310: National Defense Authorization Act for Fiscal Year 2013 - SECTION 901--ADDITIONAL DUTIES OF DEPUTY ASSISTANT SECRETARY OF DEFENSE FOR MANUFACTURING AND INDUSTRIAL BASE POLICY AND AMENDMENTS TO STRATEGIC MATERIALS PROTECTION BOARD

This section would amend section 139c of title 10, United States Code, by directing additional duties of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy. The duties would include prescribing policies and procedures for ensuring reliable sources of materials that are critical to national security. This section would also amend section 187 of title 10, United States Code, by reconfiguring the Strategic Materials Protection Board to include: the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy; an official within the Defense Logistics Agency with responsibility for strategic materials; and designees from the Army, the Navy, and the Air Force.

SEC. 901. ADDITIONAL DUTIES OF DEPUTY ASSISTANT SECRETARY OF DEFENSE FOR MANUFACTURING AND INDUSTRIAL BASE POLICY AND AMENDMENTS TO STRATEGIC MATERIALS PROTECTION BOARD.

(a) Findings- Congress finds the following:

(1) The Defense Logistics Agency has made little progress in addressing the findings and recommendations from the April 2009 report of the Department of Defense report titled ‘Reconfiguration of the National Defense Stockpile Report to Congress’.

(2) The office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy has historically analyzed the United States defense industrial base from the point of view of prime contractors and original equipment manufacturers and has provided insufficient attention to producers of materials critical to national security, including raw materials producers.

(3) Responsibility for the secure supply of materials critical to national security, which supports the defense industrial base, is decentralized throughout the Department of Defense.

(4) The office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy should expand its focus to consider both a top-down view of the supply chain, beginning with prime contractors, and a bottom-up view that begins with raw materials suppliers.

(5) To enable this focus and support a more coherent, comprehensive strategy as it pertains to materials critical to national security, the office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy should develop policy, conduct oversight, and monitor resource allocation for agencies of the Department of Defense, including the Defense Logistics Agency, for all activities that pertain to ensuring a secure supply of materials critical to national security.

(6) The Strategic Materials Protection Board should be reconfigured so as to be chaired by the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy and should fully execute its duties and responsibilities.

(b) Appointment of Deputy Assistant Secretary- Section 139c(a) of title 10, United States Code, is amended by striking 'appointed by' and all that follows through the end of the subsection and inserting 'appointed by the Secretary of Defense.'.

(c) Responsibilities of Deputy Assistant Secretary- Section 139c(b) of such title is amended--

(1) by striking paragraphs (1) through (4) and inserting the following:

'(1) Providing input to strategy reviews, including quadrennial defense reviews conducted pursuant to section 118 of this title, on matters related to--

'(A) the defense industrial base; and

'(B) materials critical to national security.

'(2) Establishing policies of the Department of Defense for developing and maintaining the defense industrial base of the United States and ensuring a secure supply of materials critical to national security.

'(3) Providing recommendations to the Under Secretary on budget matters pertaining to the industrial base, the supply chain, and the development and retention of skills necessary to support the industrial base.

'(4) Providing recommendations and acquisition policy guidance to the Under Secretary on supply chain management and supply chain vulnerability throughout the entire supply chain, from suppliers of raw materials to producers of major end items.'.

(2) by striking paragraph (5) and redesignating paragraphs (6), (7), (8), (9), and (10) as paragraphs (5), (6), (7), (8), and (9), respectively;

(3) by inserting after paragraph (9), as so redesignated, the following new paragraph (10):

'(10) Providing policy and oversight of matters related to materials critical to national security to ensure a secure supply of such materials to the Department of Defense.'.

(4) by redesignating paragraph (15) as paragraph (18); and

(5) by inserting after paragraph (14) the following new paragraphs:

'(15) Coordinating with the Director of Small Business Programs on all matters related to industrial base policy of the Department of Defense.

‘(16) Ensuring reliable sources of materials critical to national security, such as specialty metals, armor plate, and rare earth elements.

‘(17) Establishing policies of the Department of Defense for continued reliable resource availability from domestic sources and allied nations for the industrial base of the United States.’.

(d) Materials Critical to National Security Defined- Section 139c of such title is further amended by adding at the end the following new subsection:

‘(d) Materials Critical to National Security Defined- In this section, the term ‘materials critical to national security’ has the meaning given that term in section 187(e)(1) of this title.’.

(e) Amendments to Strategic Materials Protection Board-

(1) MEMBERSHIP- Paragraph (2) of section 187(a) of such title is amended to read as follows:

‘(2) The Board shall be composed of the following:

‘(A) The Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy, who shall be the chairman of the Board.

‘(B) The Administrator of the Defense Logistics Agency Strategic Materials, or any successor organization, who shall be the vice chairman of the Board.

‘(C) A designee of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology.

‘(D) A designee of the Assistant Secretary of the Navy for Research, Development, and Acquisition.

‘(E) A designee of the Assistant Secretary of the Air Force for Acquisition.’.

(2) DUTIES- Paragraphs (3) and (4) of section 187(b) of such title are each amended by striking ‘President’ and inserting ‘Secretary’.

(3) MEETINGS- Section 187(c) of such title is amended by striking ‘Secretary of Defense’ and inserting ‘Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy’.

(4) REPORTS- Section 187(d) of such title is amended to read as follows:

‘(d) Reports- (1) After each meeting of the Board, the Board shall prepare a report containing the results of the meeting and such recommendations as the Board determines appropriate. The Secretary of each military department shall review and comment on the report.

‘(2) Each such report shall be published in the Federal Register and subsequently submitted to the congressional defense committees, together with public comments and comments and recommendations from the Secretary of Defense, not later than 90 days after the meeting covered by the report.’.

C. Keynote Speaker Bios

David Cammarota

David Cammarota is the materials specialist within the Office of Manufacturing and Industrial Base Policy at the Department of Defense. The office is responsible for ensuring that a reliable and cost effective industrial base exists in order to support the war fighter. Mr. Cammarota focuses on the capabilities of materials supply chains within the industrial base and provides analysis and policy advice to senior decision makers regarding their vitality.

Prior to joining the Department, he spent 26 years working in the International Trade Administration of the Department of Commerce supporting efforts to enhance the competitiveness of the U.S. manufacturing base. Most recently, Mr. Cammarota served as the Director of the Office of Materials Industries, serving as the principal liaison between the Department and the metals, chemicals, and forest products industries. In this capacity, Mr. Cammarota was responsible for overseeing a program which undertook analyses of the impacts on these industries of domestic regulations and trade agreements, as well as conducted export promotion activities. In addition, he provided policy recommendations to the Department's senior decision makers on domestic and international issues impacting the competitiveness of these industries.

Mr. Cammarota has a B.S. in geology from Virginia Tech and an M.S. in mineral economics from Penn State.

Andy Davis

Following two years as a strategy and government relations consultant for Molycorp, Mr. Davis joined the company in February 2011, and he helps manage the company's government and public relations. Mr. Davis' previous consulting work for Molycorp helped to direct and elevate Washington's attention to rare earths, the supply and demand challenges, and the nation's supply chain vulnerabilities.

Prior to joining Molycorp in-house, Mr. Davis was a Vice President at McBee Strategic Consulting, where he provided strategic policy and political guidance, message development, and federal legislative advocacy for venture capital-backed clean energy technology companies. He also helped clients navigate federal financing support mechanisms, including the Department of Energy's Loan Guarantee Program.

A 10-year veteran of Capitol Hill and political communication, Mr. Davis served as the Communications Director for the U.S. Senate Commerce, Science, and Transportation Committee under Senator Daniel Inouye and, previously, for Senator Ernest "Fritz" Hollings, where he managed the communications strategy and media relations for a wide variety of the Committee's high-profile issues, including the post-9/11 transportation security laws, the Enron investigation, fuel efficiency standards, and American competitiveness. In 2004, Mr. Davis served as the Communications Director in Senator John Kerry's Senate office during his run for the presidency. He began his Senate career as part of Senate Minority Leader Tom Daschle's leadership communications staff.

Mr. Davis left the Hill in 2006 to attend the University of Michigan's Ross School of Business, where he focused on business models and strategies that blend financial value with environmental and social value. He received his MBA in April 2008. A Colorado native, Mr. Davis holds Bachelor of Arts degrees in International Affairs and Political Science from the University of Colorado at Boulder. He and his wife Sue Bell live in Arlington.

John Fischer, Ph.D.

John Fischer currently serves as the Director of Defense Laboratory Programs. In this position, he is responsible for the development and implementation of policies for the DoD's laboratory system. Prior to this position, he spent 25 years in the Department of the Navy, initially as a research chemist focused on development of new explosives, propellants, and nonlinear optical materials.

Dr. Fischer was appointed to the Senior Executive Service in 1998 and served as the Associate Director of the Naval Aviation Science and Technology Office and head of the Research Department at the Naval Air Warfare Center Weapons Division, China Lake, California.

In 2006, he was appointed civilian director of NAVAIR's Systems Engineering Department. In this position, he was the lead for Naval Aviation Systems Engineering tasking and functions for the complete life cycle of all aviation and aviation related systems. In 2008, Dr. Fischer was assigned additional duty as NAVAIR Chief Technology Officer responsible for the development and implementation of the Naval Aviation Enterprise Science & Technology program.

Dr. Fischer has a bachelor's degree (cum laude) in Chemistry from Lawrence University, and a doctorate in Organic Chemistry from Northern Illinois University. He also served as a post-doctoral research chemist at the Ohio State University from 1982 to 1984.

Christopher Guzy, Ph.D.

Christopher Guzy joined Ballard as Vice President and Chief Technology Officer in February 2005. Dr. Guzy's areas of responsibility include product development and technology research and development.

Prior to joining Ballard, Dr. Guzy was General Manager of GE Healthcare's product development and supply chain operations in Hungary. During his 17 years at General Electric in the United States and Europe, he also held a number of other senior technology and product development leadership positions including Global General Manager of Linear Fluorescent Technology and Vice President and Director of Quality and Technology, Europe for GE Lighting. Prior to joining GE, he led a process development section at Nestlé in Switzerland.

Dr. Guzy began his career as Station Director of the School of Chemical Engineering Practice and Assistant Professor of Chemical Engineering at the Massachusetts Institute of Technology from 1983 to 1986. He holds Bachelor and Master of Science degrees in Chemical Engineering from Clarkson University and a Doctorate in Chemical Engineering from the University of New Mexico.

Gregory Jackson, Ph.D.

Greg Jackson has been a Professor in the Department of Mechanical Engineering at the University of Maryland, where he joined the faculty in 1997. He serves as the Associate Director of the campus-wide Univ. of Maryland Energy Research Center. He directs research in the Ballard Power Fuel Cell Systems Laboratory on PEM fuel cell systems and electrocatalysis, solid oxide fuel cells, and catalytic reactions for energy conversion and H_2 production. His research in PEM fuel cells research includes fundamental studies on nano-architectured electrocatalysis for CO-tolerant anodes and system level research on hydrocarbon fuel processing for PEM fuel cells in collaboration with Ballard Power Systems for portable and distributed power applications. His group's research in solid oxide fuel cell materials includes exploration of material architectures that allow for effective utilization of hydrocarbons as well as experiments to validate SOFC design models. Dr. Jackson received his Ph.D. from Cornell University in Mechanical Engineering. After Cornell, Dr. Jackson spent several years at Precision Combustion Inc., where he managed projects related to catalytic systems for ultra-low-NOx combustion and for ignition stabilization in diesel engines and gas turbines.

Robert Moore, Ph.D.

Robert B. Moore is a Professor of Chemistry at Virginia Tech, and the Associate Director for Research and Scholarship at the Institute for Critical Technology and Applied Science (ICTAS). He received his Ph.D. in Analytical Chemistry from Texas A&M University in 1988, followed by a postdoctoral fellowship in the Department of Chemistry at McGill University in Montreal, Quebec. In 1991, he joined the faculty of the Department of Polymer Science at The University of Southern Mississippi, where he served for 17 years. In 2007, he moved to Virginia Tech to join the faculty in the Department of Chemistry. Professor Moore has authored over 185 publications covering his research in areas ranging from polymeric materials for energy applications, and nanocomposites, to artificial muscles. Aside from his research activities, Dr. Moore is also the Associate Director for Research and Scholarship at the Institute for Critical Technology and Applied Science of Virginia Tech. He is also the immediate past Chair of the Polymer Chemistry Division of the American Chemical Society.

Kamen Nechev, Ph.D.

Kamen Nechev is Chief Technology Officer at Saft Groupe SA in Cockeysville, MD. Dr. Nechev earned his BS degree in Mechanical Engineering from Technical University of Ruse, Bulgaria, where he subsequently was an Assistant Professor. He completed Masters of Science and PhD in Materials Science and Electrochemistry at Florida Atlantic University where he graduated in 1996. He has been with Saft since 1999. He became the Li-ion R&D Manager in Cockeysville, MD in 2004 and since 2010 he has been the Chief Technical Officer for the company. He has worked on Ni-MH, Ag-Zn and Li-ion batteries as well as supercapacitors.

D. List of Participants

1	Prof.	Steve	Brown	Catholic University	brownjs@cua.edu
2	Mr.	David	Cammarota	OSD	David.Cammarota@osd.mil
3	Mr.	Kevin	Cook	NAVSEA 05	kevin.l.cook@navy.mil
4	Mr.	Andy	Davis	Molycorp	andy.davis@molycorp.com
5	Mr.	Peter	Dent	Electron Energy Corp.	pcd@electronenergy.com
6	Dr.	Norbert	Doerry	NAVSEA 05	norbert.doerry@navy.mil
7	Mr.	Daniel	Eichles	Georgetown University	
8	Dr.	Millard	Firebaugh	CECD, University of Maryland	millfirebaugh@comcast.net
9	Dr.	John	Fischer	OSD	John.Fischer@osd.mil
10	Dr.	William	Frazier	NAVAIR	william.frazier@navy.mil
11	Dr.	Christopher	Guzy	Ballard	chris.guzy@ballard.com
12	Mr.	Dylan	Hazelwood	CECD, University of Maryland	dylan@umd.edu
13	Prof.	Gregory	Jackson	CECD and UMERC, University of Maryland	gsjackso@umd.edu
14	Mr.	Robert	Kaczmarek	NSWC IHD	robert.kaczmarek@navy.mil
15	Mr.	Robert	Kavetsky	ETC	rkavetsky@etcmd.com
16	Ms.	Karen	Long	NSWC DL	karen.j.long@navy.mil
17	Ms.	Jennifer	McGraw	ETC	lilyguenivere@verizon.net
18	Mr.	William	Mick	CSC	wmick@csc.com
19	Mr.	Steve	Moffitt	Capstone National Partners	smoffitt@capstonenp.com
20	Prof.	Robert	Moore	Virginia Tech	rbmoore3@vt.edu
21	Dr.	Elan	Moritz	ETC	emoritz@etcmd.cm
22	Dr.	Kamen	Nechev	Saft Groupe SA	Kamen.Nechev@saftbatteries.com
23	Ms.	Ania	Picard	CECD, University of Maryland	picard@cecd.umd.edu
24	Mr.	Helmut	Portmann	NOAA/NDBC	Helmut.Portmann@noaa.gov
25	Dr.	Charles	Rong	Army Research Lab	charles.c.rong.civ@mail.mil
26	Dr.	James	Short	CECD, University of Maryland	James.Short@osd.mil
27	Prof.	Eric	Wachsman	UMERC, University of Maryland	ewach@umd.edu