*A PERSPECTIVE ON*

# THE NATIONAL ACADEMIES AND DOD MATERIALS AND MANUFACTURING

TREM
22 March 11

Maj Gen (Ret) Robert H. Latiff, Ph.D.
RLatiff Associates
Chair, National Materials and Manufacturing Board

# Caveats

- Personal views only
- Do Not Represent
  - Department of Defense
  - The National Academies

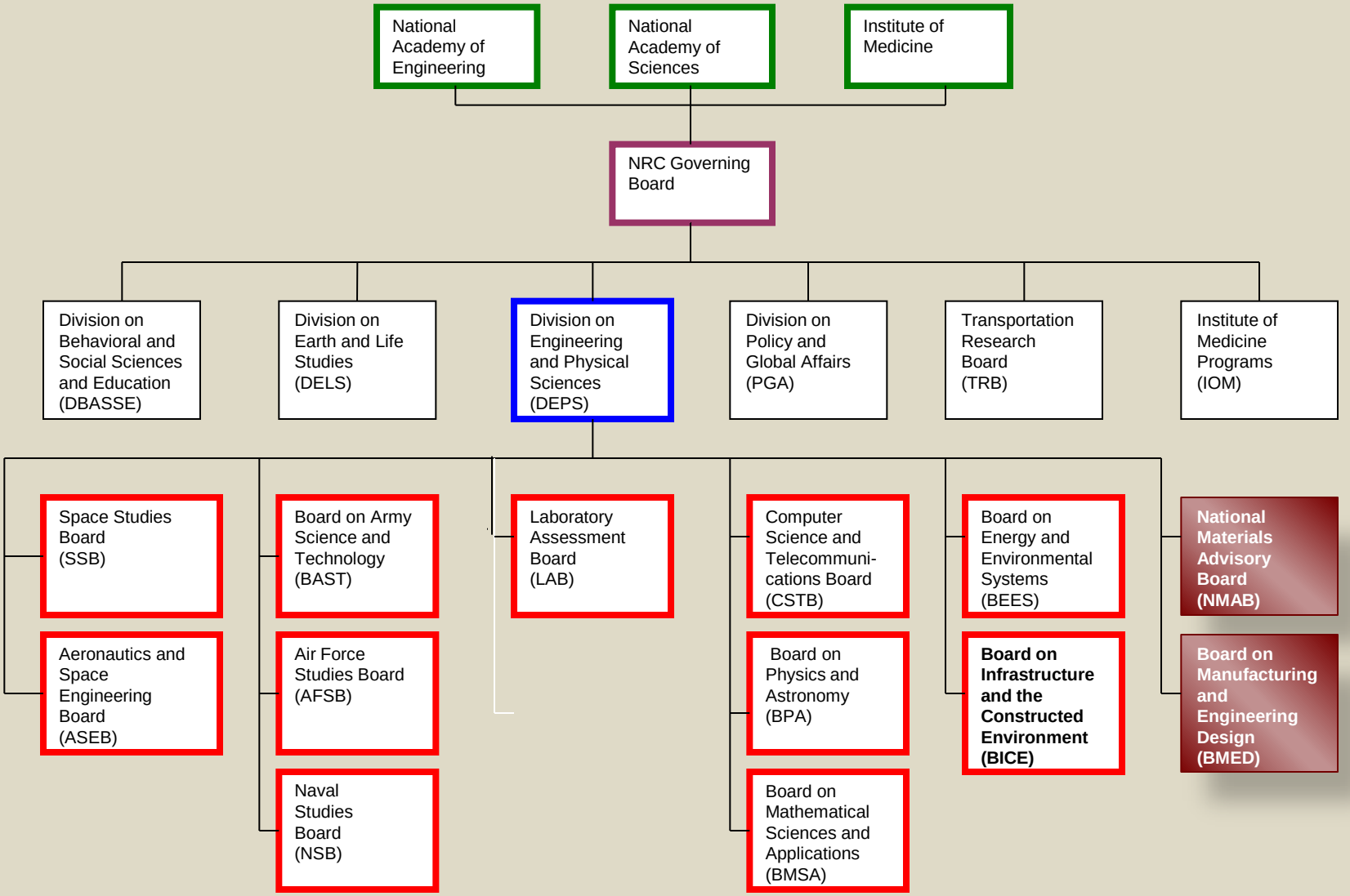
# Topics

- The National Academies
- Managing Materials for a 21st Century Military
- Congressional Requirements and DOD Response
- Defense Science and Technology Initiative

# NATIONAL ACADEMIES

- National Academy of Sciences (1863)
- National Research Council (1916)
- National Academy of Engineering (1964)
- Institute of Medicine (1970)

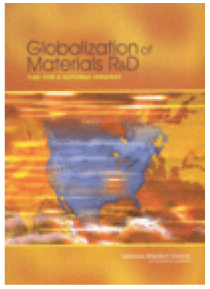
# The National Academies



# National Materials and Manufacturing Board (2011)

- National *Materials* Advisory Board (NMAB)
- Board on *Manufacturing* and Engineering Design (BMED)

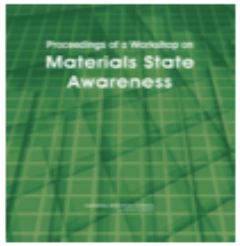
# Selected NMMB Studies




**Globalization of Materials R&D: Time for a National Strategy**

Committee on Globalization of Materials Research and Development, National Research Council

ISBN: 978-0-309-09603-4, 216 pages, 7 x 10, paperback (2005)

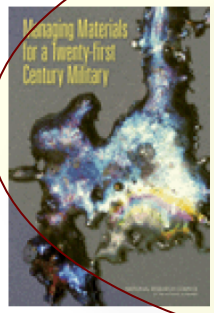



**Proceedings of a Workshop on Materials State Awareness**

Emily Ann Meyer, Editor, National Research Council

ISBN: 0-309-12166-3, 76 pages, 8 1/2 x 11, (2008)






**Managing Materials for a Twenty-first Century Military**

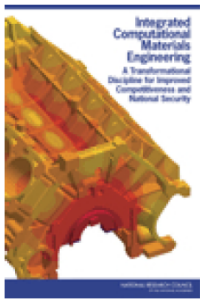
Committee on Assessing the Need for a Defense Stockpile, National Research Council

ISBN: 978-0-309-11257-4, 208 pages, 7 x 10, paperback (2008)


**Accelerating Technology Transition: Bridging the Valley of Death for Materials and Processes in Defense Systems**

Committee on Accelerating Technology Transition, National Research Council

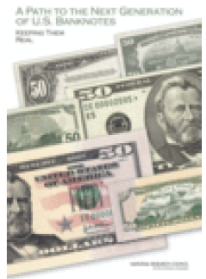
ISBN: 978-0-309-09317-0, 68 pages, 8 1/2 x 11, paperback (2004)




**Integrated Computational Materials Engineering: A Transformational Discipline for Improved Competitiveness and National Security**

Committee on Integrated Computational Materials Engineering, National Research Council

ISBN: 978-0-309-11999-3, 152 pages, 7 x 10, paperback (2008)



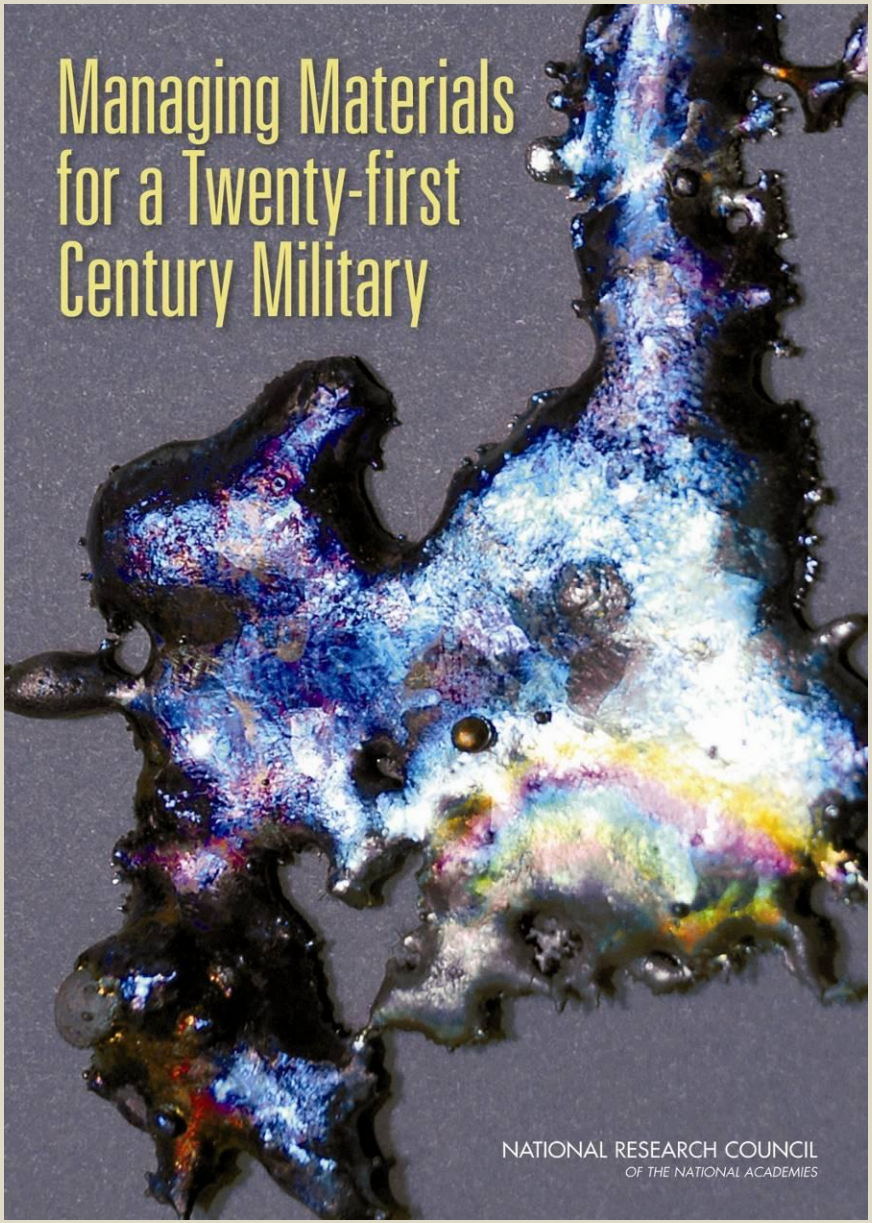

**A Path to the Next Generation of U.S. Banknotes: Keeping Them Real**

Committee on Technologies to Deter Currency Counterfeiting, National Research Council

ISBN: 978-0-309-10574-3, 328 pages, 7 x 10, (2007)

# Relevance of National Academy Efforts

- Globalization of Materials R&D *(Education and Training)*
  - Effects of outsourcing
  - Diminished technology dominance
- ICME *(Technology and Business Practices)*
  - Advanced manufacturing techniques
  - Net-centric, cloud, data intensive, on-demand
- Managing Materials *(Education, Infrastructure, Regulation)*
  - Competition for critical materials
  - Diminished processing abilities
  - Increased need for data
- Propulsion Materials *(Education, Infrastructure, Technology and Business Practices) – currently in security review*
  - Loss of technology dominance
  - Reduced funding
  - Limited programs
- Accelerating Technology Transition *(Technology and Business Practices)*




## Committee on Assessing the Need for a Defense Stockpile

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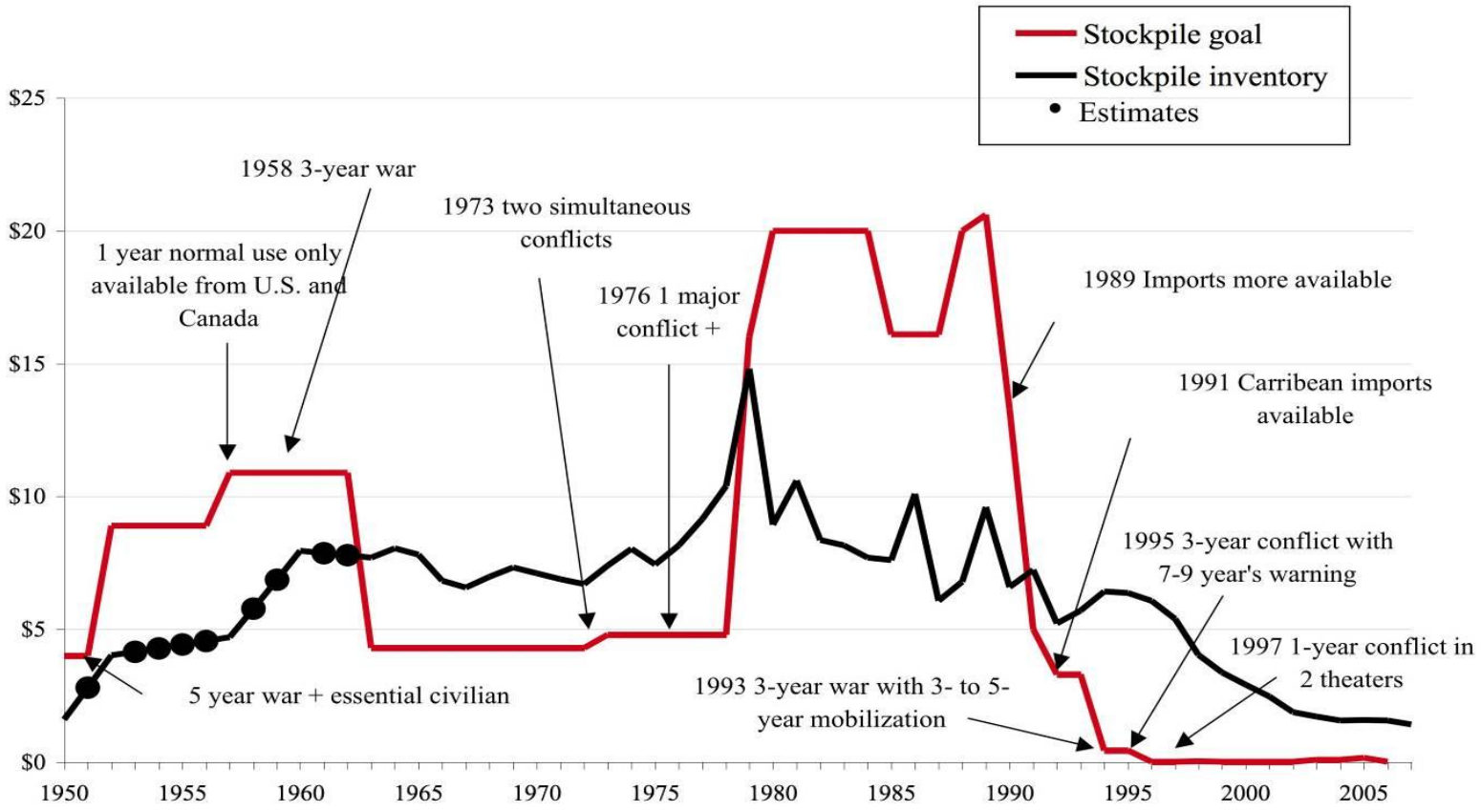
# Stockpile Over Time

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# The Conclusions From the NMAB Report Seemed to be Clear

- The current design, structure, and operation of the National Defense Stockpile render it ineffective in responding to modern needs and threats.
- The Department of Defense does not appear to fully understand its needs for specific materials nor does it have adequate information on their supply.
- Lack of good data and information, both domestic and offshore, on the availability of materials impedes the effective management of defense-critical supply chains.
- Need for a new approach in the form of a national defense-materials management system.

*From "Managing Materials for a Twenty-First Century Military"*

# DOD Report To Congress
# Reconfiguration of the National Defense Stockpile
# April 2009

- In Response To
  - HR 1815, NDAA, FY06
  - HR 5122, NDAA, FY07, (HR Rep 109-89)
  - DOD Appropriations Bill 2008 (HR Rep109-452, S. Rep 110-155)
- Concluded
  - No longer rely on US buying power
  - Need greater latitude to react to markets
  - Must better align materials with military needs
  - Suspend sales of thirteen commodities
    - Monitor, strategize thirty nine others

# Materials Sales Suspended

| COMMODITY | DEFENSE USE | COUNTRIES OF ORIGIN | REMAINING INVENTORY | % IMPORT DEPENDENCE |
|---|---|---|---|---|
| Zinc | Galvanizing agent for steel | Canada, Peru, Mexico, Australia | 8,264 Short Tons | 58 |
| Tin | Anti-corrosive, alloying agent | Peru, Bolivia, China, Indonesia | 3,863 Metric Tons | 79 |
| Iridium | Hardening agent in platinum alloys | South Africa, United Kingdom, Germany, Canada | 567 Troy Ounces | 94 |
| Platinum | Catalyst; heavy-duty electrical contacts | South Africa, United Kingdom, Germany, Canada | 8,380 Troy Ounces | 94 |
| Germanium | Semiconductors and transistors, fiber optics, medical industry | Belgium, Canada, Germany, China | 17,871 Kilograms | 100 |
| FerroChrome (High Carbon and Low Carbon) | Stainless steel | China, Africa, Kazakhstan | 314,847 Short Tons | 62* |
| Tungsten Metal Powder and Tungsten Ores and Concentrate (O & C) | Steel hardening and toughening | China, Canada, Germany, Portugal | Powder - 585,619 Pounds; O&C – 46 million Pounds | 70* |
| Tantalum Carbide | Hard refractory ceramic | Australia, Brazil, China, Germany | 3,801 Pounds | 100 |
| Niobium/Columbium | Nuclear industry, superconductor | Brazil, Canada, Estonia, Germany | 22,156 Pounds | 100 |
| Cobalt | Magnetic properties, corrosion and wear resistant | Norway, Russia, Finland, China | 2.26 million Pounds | 78* |
| Ferromanganese | Used in steel production and steel deoxidizer | South Africa, Belgium, Ukraine | 526,000 Short Tons | 100 |
| Beryllium | Aerospace systems and nuclear weapons | Kazakhstan, Germany, United Kingdom | 215 Short Tons | 100 |
| Chromium Metal | Aerospace systems and high grade stainless steel | South Africa, Kazakhstan, Russia, Zimbabwe | 5,390 Short Tons | 62* |

*** Indicates where secondary material sources are included—not all such material is suited for defense purposes. Import dependency is therefore much higher for these materials.**

Table 2. OSD Survey 2008: Other Materials Causing Production Delays (19 Materials)

| Material | Recommendation |
|---|---|
| Aluminum-Lithium (AL - 2.8 Cu - 1.5 Li) | Study |
| Carbon Fiber | Study |
| Ceramic/Al Nitride/Copper | Study |
| Cerium | Study |
| Deuterium | Study |
| Europium | Study |
| Gadolinium | Study |
| Helium | Study |
| Image Intensification Tubes | Study |
| Kevlar | Study |
| Lanthanum | Study |
| Lithium | Study |
| Nomex | Study |
| PWA 1484 | Study |
| Rene N5 | Study |
| Selenium | Study |
| Steel (Specialty) | Study |
| Tritium | Study |
| Xenon | Study |

# DOD Re-Look At Selected Materials

Table 1. Risk Review of Selected Strategic Materials

| | NSE Shortage* | PSD1 Shortage** | PSD1 Near-Shortage*** | OSD Survey 2008 Identified a Problem | Recommen-dation**** |
|---|---|---|---|---|---|
| **Materials DoD Recommended for Reserve** | | | | | |
| Beryllium Metal | X | X | | X | Hold/Goal Material |
| Chromium Metal | | X | | X | Hold/Study |
| Cobalt | | X | | X | Hold/Study |
| Columbium (Niobium) | | | | X | Hold/Study |
| Ferro Chromium | | | X | | Hold/Study |
| Ferro Manganese | | | X | | Hold/Study |
| Germanium | | | X | X | Hold/Study |
| Iridium | | | X | | Hold/Study |
| Platinum | | | X | X | Hold/Study |
| Tantalum | | X | | | Hold/Study |
| Tin | | X | | X | Hold/Study |
| Tungsten | X | X | | X | Hold/Study |
| Zinc | | X | | X | Hold/Study |
| # of materials in group with shortage, near shortage, or problem (of 13) | 2 | 7 | 5 | 9 | |
| **Other Systematically Analyzed Materials** | | | | | |
| Aluminum Metal | | X | | X | Study/PB |
| Aluminum Oxide Fused Crude | | X | | | Study/PB |
| Antimony | X | X | | | Study/PB |
| Bauxite Refractory | | X | | | Study/PB |
| Beryl Ore | | X | | | Study/PB |
| Beryllium Master Copper Alloy | | | X | X | Study |
| Bismuth | | X | | | Study/PB |
| Boron | | | | | Monitor |
| Boron Composite Filaments | | | X | | Study |
| Boron Nitride | | X | | | Study/PB |
| Cadmium | | | | X | Study |
| Chromite Ore (all grades) | | | | | Monitor |
| Copper | | X | | X | Study/PB |
| Fluorspar Acid Grade | | X | | | Study/PB |
| Fluorspar Metallurgical Grade | | | | | Monitor |
| Gallium | | X | | X | Study/PB |
| Hafnium | | | X | X | Study |
| Indium | | X | | X | Study/PB |
| Lead | | X | | | Study/PB |

…list continues…

# CONCLUSION: Stockpile Should Be Reconfigured!

- Report submitted to Congress, April 2009
- Initiatives being implemented and/or ***considered*** are:
  - **Reconfigure** the NDS into the **Strategic Materials Security Program**
  - Grant the SMSP broad programmatic **flexibility**
  - **Modify the current policy** to dispose of materials in the NDS
  - Enhance the acquisition authority to employ **risk mitigation** strategies
  - Consider the need to augment the Transaction Fund with an **annual appropriation**
- HASC hearing held in July 2009.
- Implementation plan was submitted and accepted in September 2010.
- A legislative package has been prepared by DLA/DNSC and is in review.


# Rare Earth Elements: The Global Supply Chain

**Marc Humphries**
Analyst in Energy Policy

September 30, 2010

## Establish a Stockpile

Establishing a government-run economic stockpile and/or private-sector stockpiles that would contain supplies of specific REE broadly needed for "green initiatives" and defense applications is a policy advocated by some in industry and government. This may be a prudent investment. Generally, stockpiles and stockpile releases could have an impact on prices and supply but would also ensure supplies of REE materials (oxides, metals, etc.) during times of normal supply bottlenecks. An economic stockpile could be costly and risky, as prices and technology may change the composition of REEs that are needed in the economy.

According to USGS,[34] DOD along with USGS is examining which of the REEs might be necessary in the National Defense Stockpile (NDS). In the recent past, NDS materials were stored for wartime use based on a three-year war scenario. Some of the rare earth elements contained in the National Defense Stockpile were sold off by 1998. However, rare earth elements were never classified as strategic minerals.[35] DOD had stockpiled some yttrium but has since sold it off, and none of the REEs have been classified as strategic materials. A critical question for stockpile development would be: What materials along the supply chain should be stockpiled? For example, should the stockpile contain rare earth oxides or alloyed magnets which contain the REEs, or some combination of products?

The National Research Council (NRC) has produced an in-depth report on minerals critical to the U.S. economy and offers its analysis as described here: "... most critical minerals are both essential in use (difficult to substitute for) and prone to supply restrictions."[36] While the NRC report is based on several availability criteria used to rank minerals for criticality (geological, technical, environmental and social, political, and economic), REEs were determined to be critical materials assessed at a high supply risk and the possibility of severe impacts if supplies were restricted. Some of the REE applications are viewed as more important than others and some are at greater risk than others, namely the Heavy Rare Earth Elements (HREEs), as substitutes are unavailable or not as effective.[37]

The federal government and private sectors are beginning to address how to secure reliable rare earth materials (raw materials through metals and alloys) from China and non-Chinese sources in the short term, and how to rebuild the U.S. supply chain for the long term.

## H.R. 5136, the Fiscal Year 2011 National Defense Authorization Act

The House-passed bill (H.R. 5136) would require the Secretary of Defense to assess the rare earth material supply chain to determine if any of the materials were strategic or critical to national security. If the material is determined to be strategic, the Secretary would be required to develop a plan to ensure long-term availability by December 31, 2015. The Secretary shall submit a report to Congress on the assessment and the plan not later than 180 days after enactment of this legislation.

Also, based on congressional findings, among other things, there is an urgent need to eliminate U.S. vulnerability related to the supply of neodymium iron boron magnets and to restore the domestic capacity to manufacture sintered neodymium iron boron magnets used in defense applications. Within 90 days of enactment of this bill the Secretary of Defense would be required to submit a plan, to the appropriate congressional committees, to establish a domestic source of sintered neodymium iron boron magnets used in defense applications.

## P.L. 111-84, the Fiscal Year 2010 National Defense Authorization Act

In the proposed House and Senate (H.R. 2647/S. 1390) versions of the defense authorization bill for 2010, Representative Mike Coffman and Senator Evan Bayh introduced legislation to direct the Comptroller General to determine the extent to which specific military weapons systems are currently dependent upon rare-earth materials and the degree to which the United States is dependent upon sources that could be interrupted or disrupted. The measure also directed DOD to describe the risks (both current and projected) involved in the United States' dependence on foreign sources of these materials, and any steps DOD has taken or plans to take to address any potential risks to national security.[30] The measure was passed in the Fiscal Year 2010 National Defense Authorization Act.[31]

(3/2011) " DOD Continues to work on response to Congress…"

# Something Different?

## Industrial Base Considerations in the QDR

### Overview of Industrial Policy Participation

### December 3, 2009

Dawn Vehmeier
Acting Deputy Director
(Industrial Policy)

# Strengthening the Industrial Base – Theme in the QDR

- DoD's laissez-faire approach to the defense industry in the past is not appropriate for the today's complex environment
  - Defense industry has consolidated around 20th century platforms rather than the broad and flexible system of systems we will need in the future
  - Economic crisis and increased globalization call for a more active DoD role in promoting health and vitality of the defense industrial base
  - Requires a long-term approach in partnership with industry and Congress
  - Department will continue to rely on market forces whenever possible and appropriate, but is prepared to intervene when absolutely necessary
  - DoD will take a more active role in shaping an environment in which our industries can thrive and compete globally
- Department must view industry in context
  - Varies from defense-unique items (submarines, missiles, bombers) to purely commercial items and technologies (computer chips, telecommunications)
  - Mix and scope of products and services requires a sophisticated and evolved approach which takes into account items across the continuum
- Partnership with industry is necessary for success
  - DoD goods and services reach deep into overall economy – 2nd, 3rd, and 4th tier suppliers will be primary focus
  - Financial community has an important, and often overlooked, role to play
- Articulate a National Security Industrial Vision which includes:
  - Structuring programs to promote competition and innovation
  - Seeking out the best technologies worldwide
  - Pursuing a balance between leveraging the benefits of a globalized marketplace while minimizing the inherent associated risks
  - Taking into account individual programs with a more holistic view
  - Building a much more robust, interactive, and true partnership with industry

# Congressional Impatience With DOD

- Senators Murkowski, Begich, and Coffman letter to SECDEF
- Why hasn't DOD indentified critical materials?
  - Report required by legislation
- Claim DOD has dismissed the severity of the situation
- Want DOD to identify where REE are used in weapon systems
  - (As recommended by NRC study)
- DOD/IP rules out stockpile of REE

# And Others…

**SENATORS URGE ADMINISTRATION TO OPPOSE DOMESTIC AND INTERNATIONAL CHINESE MINING PROJECTS UNTIL CHINA PLAYS FAIR AND SQUARE WITH RARE EARTH ELEMENT EXPORTS** ***Schumer, Stabenow, Casey, Whitehouse Ask Sec Geithner To Direct US Reps To International Banks To Block Funding For Any Chinese Mining Project in China or Abroad – Ask Sec Salazar To Block Any Domestic Chinese Funded Mining Projects***

3/15/2011

**WASHINGTON, DC—U.S. Senators Charles E. Schumer (D-NY), Debbie Stabenow (D-MI), Robert Casey (D-PA) and Sheldon Whitehouse (D-RI) today called on administration officials to step up their fight against China's hording of critical rare earth elements (REEs). The Senators sent a letter to Treasury Secretary Timothy Geithner and Secretary of the Interior Ken Salazar urging them to use their power to block Chinese mining projects both abroad and in the United States until China agrees to participate fairly in the global trade of REEs**

# Comprehensive EU Assessment

## Critical raw materials for the EU

### Report of the Ad-hoc Working Group on defining critical raw materials

The *ad-hoc* Working Group is a sub-group of the Raw Materials Supply Group and is chaired by the European Commission

Version of 30 July 2010

Note: The full report will be available on the Enterprise and Industry Directorate General website http://ec.europa.eu/enterprise/policies/raw-materials/documents/index_en.htm

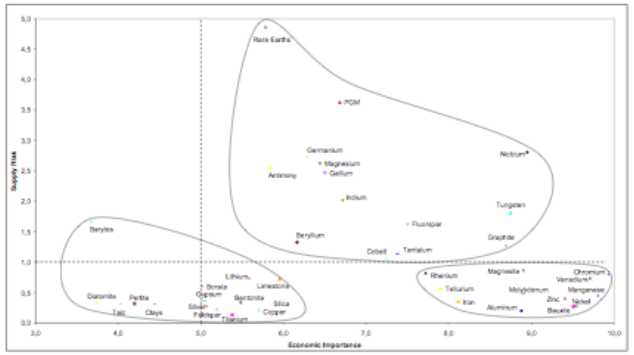
European Commission
Enterprise and Industry

We Mean Business



- It presents a transparent methodology.

Based on a criticality methodology, calculations are made regarding the economic importance and supply risk of the 41 materials.




The Group considers that those 14 raw materials falling within the top right cluster of the above diagram are critical. As noted, this is due to their high relative economic importance and to high relative supply risk. The 'environmental country risk' metric does not change this list of critical materials.

**List of critical raw materials at EU level** (in alphabetical order):

| | |
|---|---|
| Antimony | Indium |
| Beryllium | Magnesium |
| Cobalt | Niobium |
| Fluorspar | PGMs (Platinum Group Metals)[1] |
| Gallium | Rare earths[2] |
| Germanium | Tantalum |
| Graphite | Tungsten |

[1] The Platinum Group Metals (PGMs) regroups platinum, palladium, iridium, rhodium, ruthenium and osmium.
[2] Rare earths include yttrium, scandium, and the so-called lanthanides (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium)

# European Union

- Policy Oriented Recommendations
  - Land use and permitting
  - Exploration
  - Research
  - Recycling
  - Foreign investment
  - Governance
  - ***Coherence of EU policies on raw materials***
- Studying Stockpiling Options

# Defense News Op-Ed (15 Nov 2010)

- Don't let rare earth hysteria blind us to other materials issues
  - Rare Earths are the current (and real) hot issue – but not the only one
- Figure out what we really need
- Generate (coherent) policy and actions to secure supplies
  - All available avenues
- Assess our ability to process materials if we get them
- Assess our ability to manufacture once we have necessary materials
- Others are, or are moving, ahead of the US in dealing with these topics
  - China – aggressive export policies
  - China, Japan, others – Stockpile planning
  - South Korea – Stockpile consideration
  - European Union – Systems thinking, stockpile consideration
- Defense implications are significant
- Include materials and manufacturing education as a policy and funding priority

…and the silence is deafening…

# Advanced Manufacturing

- Manufacturing is a critical element of the national economy
  - And essential for national security
- Manufacturing requires
  - Capital
  - Materials
  - Expertise
- Globalization and new technology have transformed the U.S. manufacturing picture
  - Timing seems ideal for fundamental advances
  - Presents both challenges and opportunities

EXECUTIVE OFFICE OF THE PRESIDENT


# A FRAMEWORK FOR REVITALIZING AMERICAN MANUFACTURING

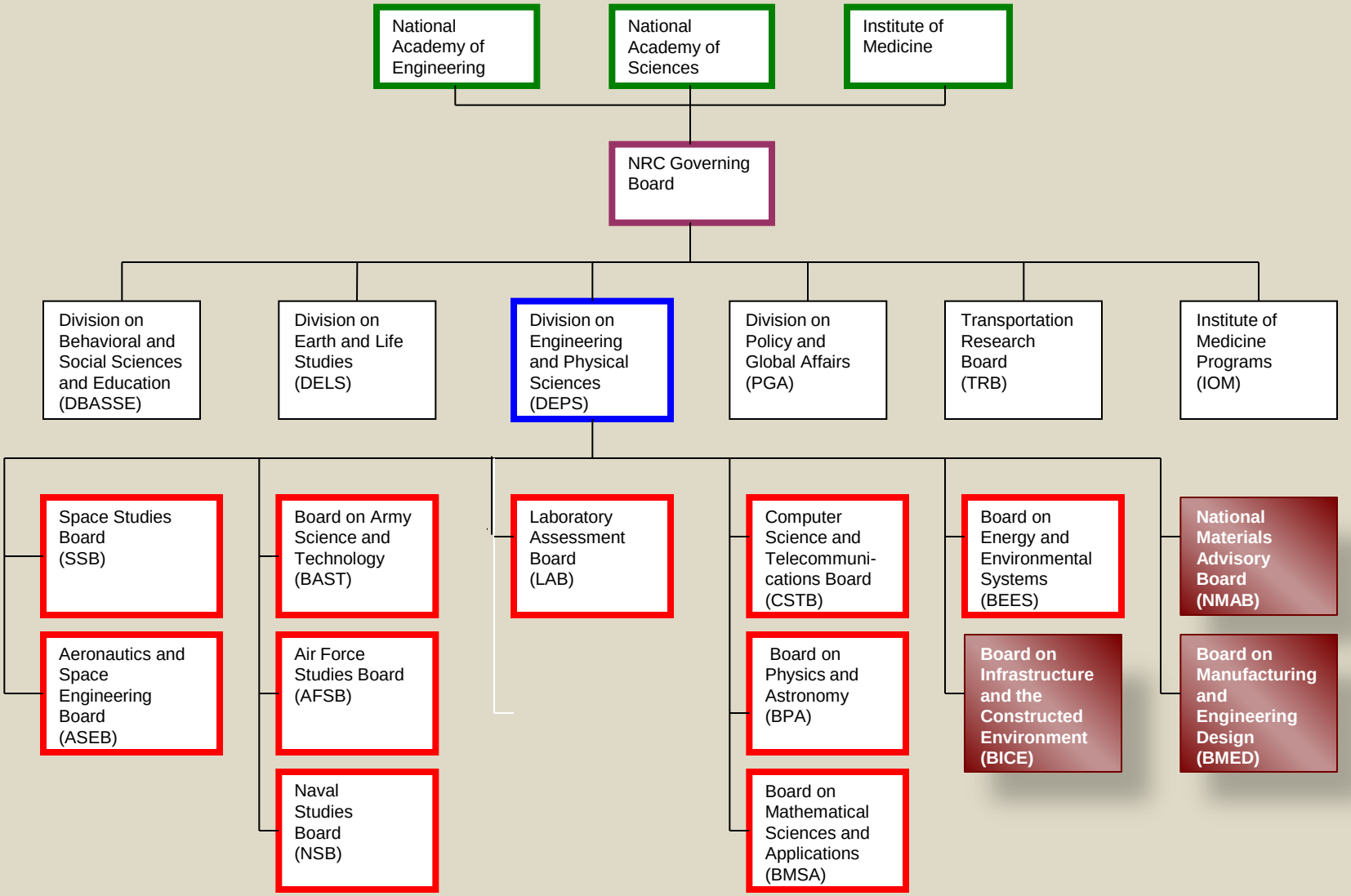
DECEMBER 2009

*Legislation Pending*

# Defense Materials, Manufacturing, and Infrastructure (DMMI) Standing Committee

- DMMI Members
  - National Materials and Manufacturing Board (NMMB)
  - Board on Infrastructure and the Constructed Environment (BICE)
    - DOD interest in fixed and forward bases, energy efficiency
  - Other experts
- Supported by DOD Project Reliance
  - DOD a consistent and long-standing supporter of NMMB (NMAB)
  - Primary emphasis is on topics critical to DOD and national security
  - Strong interest in NSF, DOE and other Federal Agency support and contributions
- Workshop/roundtable meetings
  - Brainstorming most important current and future issues
    - Access to leading experts; real-time, wide-ranging inputs
  - Development of topics for deeper study

# The National Academies



# Standing Committee on Defense Materials, Manufacturing, and Infrastructure

**Project Context and Issues:** The Department of Defense will need to address a range of systems-based, complex problems in the coming years. This standing committee will address significant issues regarding materials, manufacturing, and infrastructure-related activities. Such issues require a technical basis in order to explore the emerging scientific and technological opportunities and to inform policy decisions. Issues to be discussed will emanate from a military focus on personnel, platforms, facilities and manufacturing/industrial base, with transfer of relevant technologies to the commercial sector as appropriate. These issues will require an understanding of the interactions among materials, manufacturing and infrastructure which include, but are not limited to: maintaining technological superiority; creating energy efficient, high performance and sustainable platforms; assuring a safe, healthy, and energy efficient infrastructure; securing the safety of facilities and ports and assessing the critical availability and timeliness of the processes that provide defense materials, parts, and products. Informed approaches to addressing these issues, although assessed from a defense focus, will enable the nation to more effectively sustain technological leadership, as well as to maintain safety of people within federal and private facilities, enhance the infrastructure, and improve the manufacturing base.

# Defense S&T, Reliance 21

Defense S&T Reliance provides the *framework to enable the DoD S&T community to work together* to enhance the Defense S&T program and *eliminate unwarranted duplication*. It *strengthens cooperation* among the Services and Agencies thereby improving responsiveness to their warfighting and acquisition

## Reliance 21 Materials and Processes Community of Interest

The Defense Science and Technology (S&T) Reliance 21 Materials and Processes (M&P) Community of Interest (COI) provides materials and processes technologies ,related research and technology products, and the scientific and engineering expertise needed to maintain and enhance U.S. Defense capability. Its goals are to strengthen S&T planning by improving the integration of investments with a Department of Defense (DOD)-wide strategic view that incorporates all the Service/Agency plans and by enhancing coordination between S&T communities within DOD. It provides options to satisfy warfighter needs for performance, survivability, life extension and affordability of combat and combat support systems. The program strategy is to collaboratively plan and conduct inter-service R&D as well as to team with academia and industry to develop and make available the best technologies (including aspects of materials, manufacturing [DOD Man Tech], and infrastructure [Civil Engineering]) to our warfighting customers. Its activities include assessing the technical health of key investment areas, identifying technology trends and emerging S&T opportunities, and facilitating collaboration among stakeholders to optimize cross-Service/Agency cooperation and opportunities.

# Materials Reliance: Technical Assessment Teams

## M&P for Readiness

- NDE/I
- Prognostics/ ISHM
- Surface Protection, Corrosion Control
- Repair

## M&P for Civil Engineering

- Adaptive Protection
- Austere Entry & Maneuver
- Enterprise & Platform Enabler
- Critical Infrastructure Protection/Resiliency

## M&P for Individual Warfighter

- Soldier Protection Systems
- Soldier Enhancement
- Logistics
- Chem/Bio Defense

## Nanotechnology

## Related Working Groups

- Laser Hardening
- Low Observables
- VAATE

## M&P for Structures & Protection

- Platform M&P
  - Ferrous
  - Non-Ferrous
  - Composite
  - Polymer
  - Glassy/Nano-structure
- Survivability M&P
  - Armor
  - Blast Protection
  - Transparent Systems
- Anti-Armor
- Multifunctionality

## M&P for Propulsion & Ext. Environments

- Propulsion M&P
  - Turbine Engine
  - Scramjet, Rocket
- Thermal Protection Systems
- Materials for Complex Systems
  - EM/Rail Guns
- Reactive/Energetic Materials

## M&P for Power & Energy

- Electromechanical Conversion
  - Motors & Generators
- Power Generation
  - Solar
  - Thermal
  - Chemical
- Energy Storage
- Control & Distribution
  - Power Electronics
  - Insulators, Wire, Cable

## M&P for Sensors & Electronics

- Sensors
- Acoustic & Mechanical Sensors
- Next-generation devices
- EM Transparencies

## Metamaterials

- Sensors
- Functional Materials

# DMMI

- A sample of topics identified to-date
  - Information Framework for Integrated Computational Materials (Science and) Engineering
  - Aviation Biofuels
  - Smart Manufacturing
  - Biomaterials
  - Resilient and Sustainable Installations
  - Materials and Manufacturing Sustainability (Industrial Base)
  - National Nanoelectronics Manufacturing Capability
  - New Approaches to Performance and Design Metrics
  - Ultra-strong molecules and fibers
  - Innovation and Technology Transition

# Summary

- Real need for coherent planning and leadership
- Ongoing work of DOE and OSTP encouraging
- DOD Science and Technology community
  - Always in the forefront and strongly supportive of research in materials and manufacturing
  - Continues its active support of the National Academies
- DOD policy and National policy on REE (and other critical materials) remain elusive
  - Materials issues will not go away on their own

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# Questions/Discussion

# Materials and Manufacturing: Essential To Our Capabilities