Critical Minerals, and the U.S. Economy

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Managing Supply Chain Risks for Critical & Strategic Metals

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Study Committee

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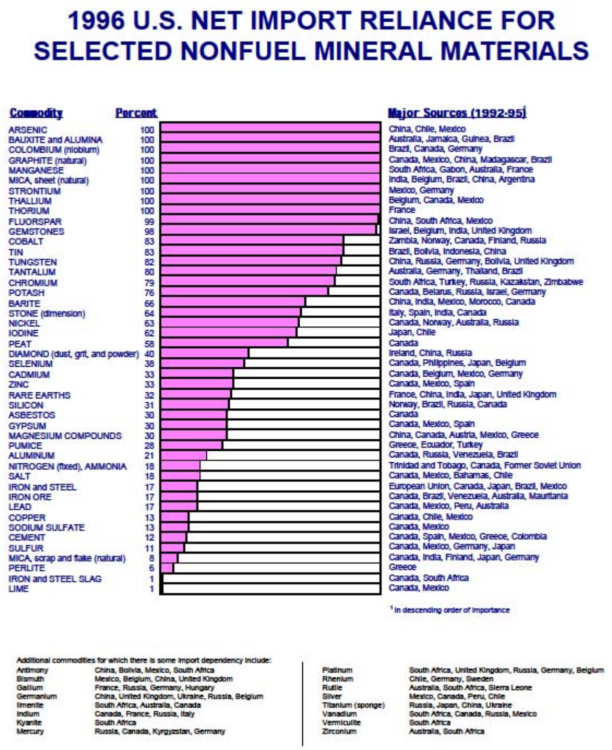
Study Goals

- Identify the minerals and mineral products that are essential for industry and emerging technologies in the domestic economy.
- Assess the trends in sources and production status of these critical minerals and mineral products worldwide.
- Examine actual or potential constraints
- Identify the impacts of disruptions on the domestic workforce and economy
- Describe and evaluate the current mineral information
- Identify types of information and possible research initiatives that will enhance understanding of critical minerals and mineral products in a global context.

Mineral Imports in 1996



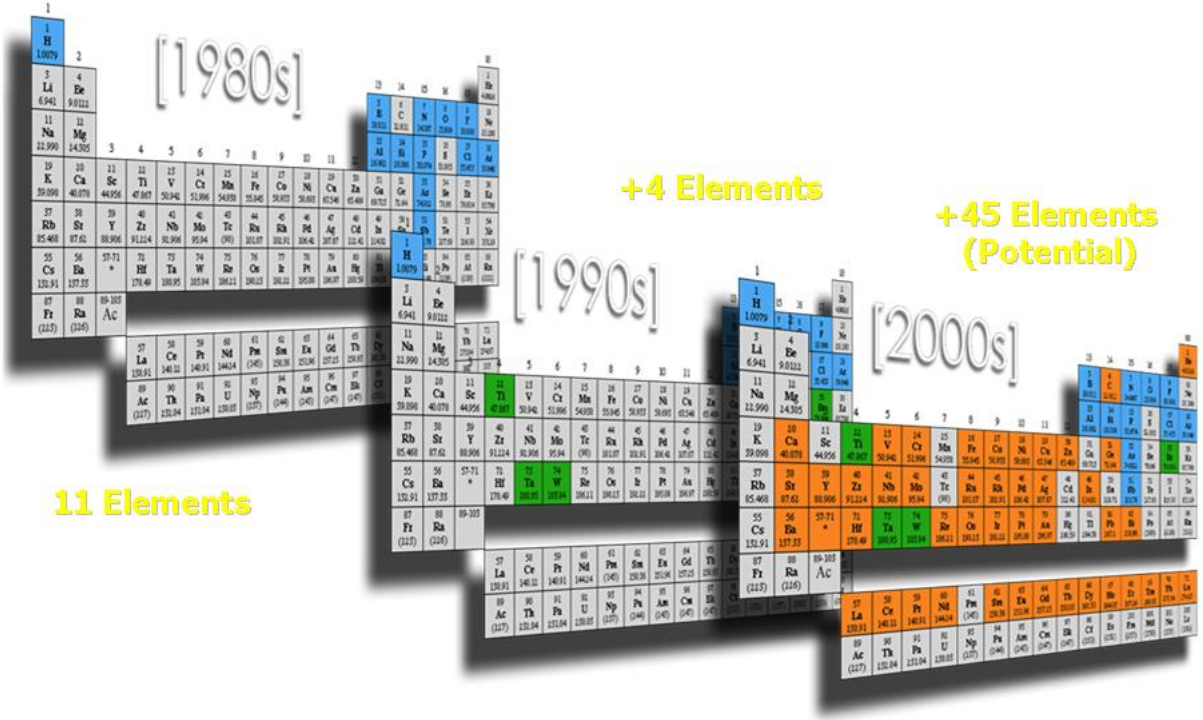
2005 U.S. NET IMPORT RELIANCE FOR SELECTED NONFUEL MINERAL MATERIALS

Commodity	Percent	Major Import Sources (2001-04)[1]
ARSENIC (trioxide)	100	China, Morocco, Chile, Mexico
ASBESTOS	100	Canada
BAUXITE and ALUMINA	100	Jamaica, Australia, Guinea, Suriname
COLUMBIUM (niobium)	100	Brazil, Canada, Estonia, China
FLUORSPAR	100	China, South Africa, Mexico
GRAPHITE (natural)	100	China, Mexico, Canada, Brazil
INDIUM	100	China, Canada, Japan, Russia
MANGANESE	100	South Africa, Gabon, Australia, China
QUARTZ CRYSTAL (industrial)	100	Brazil, Germany, Madagascar, Canada
RARE EARTHS	100	China, France, Japan, Austria
RUBIDIUM	100	Canada
STRONTIUM	100	Mexico, Germany
THALLIUM	100	Belgium, Russia, Netherlands, France
THORIUM	100	France
VANADIUM	100	Czech Republic, Canada, South Africa, Swaziland
YTTRIUM	100	China, Netherlands, Japan, Austria
GALLIUM	99	China, France, Japan, Russia
GEMSTONES	99	Israel, India, Belgium
BISMUTH	95	Belgium, Mexico, China, United Kingdom
TIN	93	Peru, China, Bolivia, Indonesia
PLATINUM	91	South Africa, United Kingdom, Germany, Canada
TANTALUM	91	Australia, Canada
STONE (dimension)	88	Italy, India, Canada, Spain
DIAMOND (natural industrial stone)	84	Ireland, Russia, Switzerland, Belgium
ANTIMONY	82	China, Mexico, Belgium, South Africa
BARITE	82	China, India
IODINE	82	Chile, Japan, Netherlands
RHENIUM	81	Chile, Kazakhstan, Germany
POTASH	80	Canada, Belarus, Russia, Germany
COBALT	78	Finland, Norway, Russia, Canada
PALLADIUM	78	Russia, South Africa, United Kingdom, Belgium
TUNGSTEN	70	China, Canada, Germany, Portugal
CHROMIUM	69	South Africa, Kazakhstan, Zimbabwe, Russia
TITANIUM MINERAL CONCENTRATES	63	South Africa, Australia, Canada, Ukraine
MAGNESIUM METAL	61	Canada, Russia, China, Israel
TITANIUM (sponge)	60	Kazakhstan, Japan, Russia
SILVER	57	Mexico, Canada, Peru, Chile
MAGNESIUM COMPOUNDS	56	China, Canada, Australia, Austria
PEAT	55	Canada
NICKEL	54	Canada, Russia, Norway, Australia
SILICON	52	Brazil, South Africa, Canada, Venezuela
ZINC	52	Canada, Mexico, Peru
ALUMINUM	47	Canada, Russia, Venezuela, Brazil
DIAMOND (dust, grit and powder)	43	Ireland, China, Ukraine, Russia
NITROGEN (fixed), AMMONIA	41	Trinidad and Tobago, Canada, Russia
COPPER	40	Canada, Chile, Peru, Mexico
GARNET (industrial)	40	Australia, India, China, Canada
VERMICULITE	35	South Africa, China
MICA, scrap and flake (natural)	32	Canada, India, China, Finland
GYPSUM	29	Canada, Mexico, Spain, Dominican Republic
CEMENT	25	Canada, Thailand, China, Venezuela
PERLITE	24	Greece
SULFUR	23	Canada, Mexico, Venezuela
PUMICE	22	Greece, Italy, Turkey
SALT	21	Canada, Chile, Mexico, The Bahamas
IRON and STEEL	15	Canada, European Union, Mexico, Brazil
GOLD	8	Canada, Peru, Colombia, Brazil
IRON and STEEL SLAG	8	Canada, France, Italy, Japan
PHOSPHATE ROCK	7	Morocco
IRON ORE	4	Canada, Brazil, Chile, Australia
TALC	3	China, Canada, France, Japan
FELDSPAR	2	Mexico, Turkey
LIME	1	Canada, Mexico

[1]In descending order of import share

Reference: USGS Mineral Commodity Summaries (2006)

Rapidly changing mineral demands
Example: computer chips



As a result, the Committee on Earth Resources of the National Research Council was concerned about:

- the security of the supply of mineral resources;
- the publicly accessible information available to assess this issue.

Background

- **Nonfuel minerals are essential for U.S. economic activity and quality of life: e.g., cellular telephones, automobiles, computers, flat-screen displays.**
- **Mineral demands and supply chains are increasingly complex.**
- **Many existing and emerging technologies require nonfuel minerals that are not available in the United States.**

What Do We Mean by Critical?

- ***By critical is meant that the loss, reduced access to, or significant cost increase of a mineral or mineral product, would cause a serious disruption in manufacturing, reduction in performance, or unacceptable price increase, of a manufactured product.***

Materials Information for Assessing Criticality

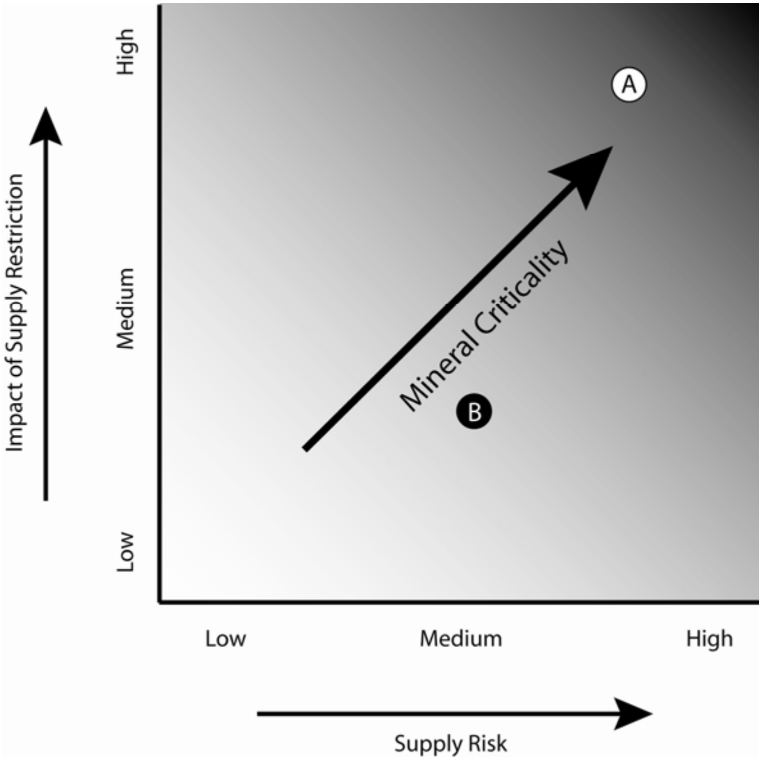
- **The federal government has an essential role in collecting and assessing minerals information. "Principal" statistical agencies, such as the Energy Information Administration, perform a vital function in collecting information.**

- **Although it is not a "principal" statistical agency, the USGS Minerals Information Team (MIT) is the most comprehensive source for minerals information.**

Development of a Tool to Identify Criticality

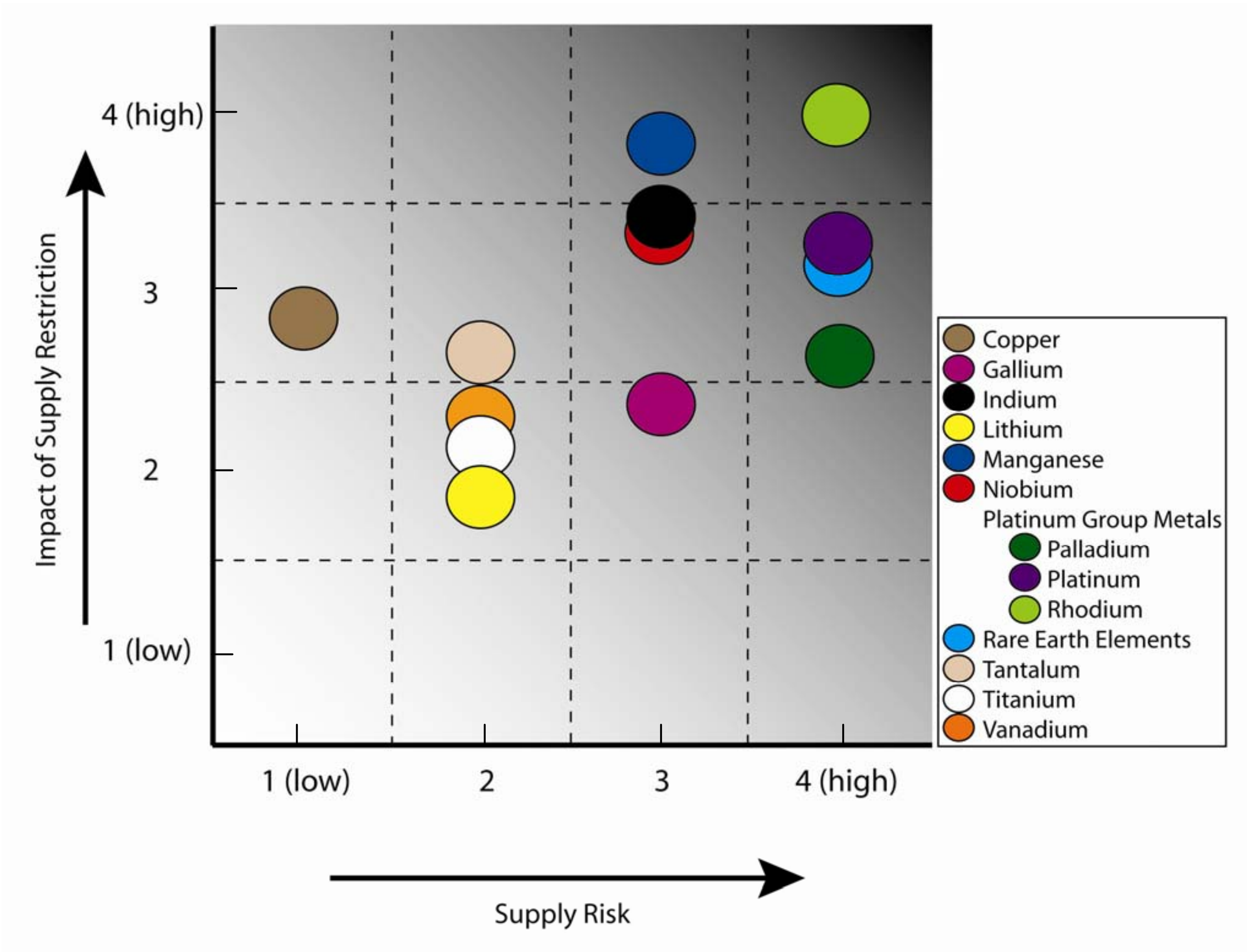
- **The Criticality Matrix:**
  - **Compares supply risk with impact of supply restriction**

Criticality Matrix



- Criticality is dynamic.
- Criticality is ‘more or less’, not ‘either/or’.
- Degree of criticality is determined by: importance in use (vertical axis) and supply risk (horizontal axis).
- Report evaluates 11 minerals to demonstrate use of the matrix: copper, gallium, indium, lithium, manganese, niobium, platinum group metals, rare earth elements, tantalum, titanium, vanadium.

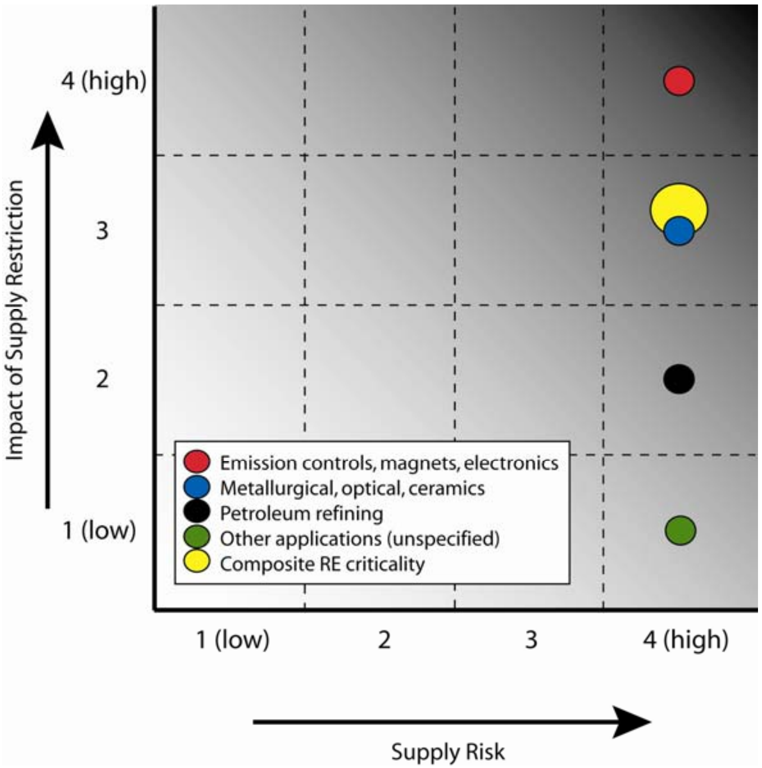
11 Minerals Evaluated



Example—Rare earth elements

- Applications: catalytic converters, permanent magnets, portable disk drives, liquid crystal displays (cell phones, PC monitors), fiber optics, optical glass.
- Rare earth chemical and physical properties make substitution with other minerals difficult.
- Important applications use 79% of total rare earth’s used in U.S. annually.
- Only U.S. rare earth production at Mountain Pass, California; mine closed to active operation in 2002.
- U.S. essentially 100% dependent on imported rare earth elements with 76% from China, and 9% from France.
- Recycling not widely practiced, so secondary sources difficult to establish.

Example—Rare earth elements



- Vertical axis: Impact of supply restriction, ranking 1 (low) to 4 (high) for individual application groups.
- Vertical axis: Composite, weighted impact of supply restriction = **3.15** (*yellow*)
- Horizontal axis: Risk to supply, rank 1 (low) to 4 (high) for supply factors (geologic, technical, social and environmental, political, economic).
- Horizontal axis: Low possibility for new domestic geologic source (4); nearly 100% import reliant with large concentration 1 supplier (4).

Example—Platinum Group Metals (PGMs)

- Applications: catalytic converters, industrial chemicals (e.g., fertilizers, explosives, caustic soda), crude oil refining, fuel cells, fine jewelry, dental and electronics.

- PGM chemical and physical properties make substitution with other minerals difficult or impossible; e.g., '*no-build*' situation for automobiles if rhodium, platinum, and/or palladium are unavailable for automobile catalyst applications.

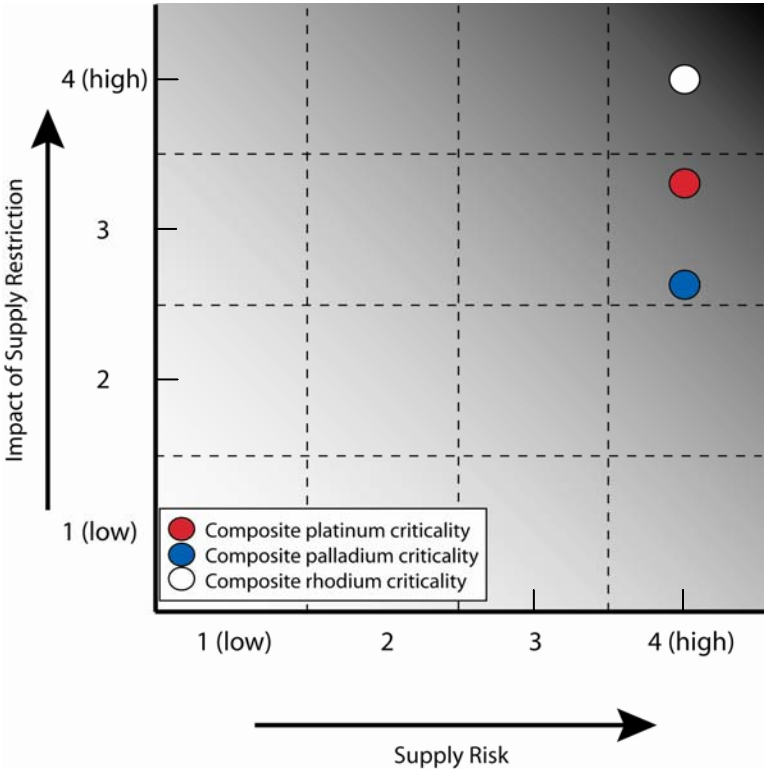
- Most important application: auto catalysts for emission controls use 50-85% of total rhodium, platinum, and palladium available annually in the United States. Industrial chemical applications use 16-25%.

- U.S. is highly dependent on imports from two countries (South Africa and Russian Federation).

- In the two countries, ten mining companies and smaller number of smelting and refining companies account for all production.

- U.S. secondary production from scrap is significant for PGMs. Supply would be at greater risk if the U.S. did not recycle.

Example—Platinum Group Metals (PGMs)



- Vertical axis: Impact of supply restriction for auto catalysts and chemicals is high.

- Horizontal axis: Reliance on imports with supply controlled by a small number of companies in two countries yields a high supply risk.

Conclusions

1. All minerals are critical to some degree. The degree of criticality changes as technologies evolve and new products are developed.

Criticality is dynamic.

2. The matrix approach is a tool to evaluate a mineral's criticality in a balanced manner for various circumstances. The degree of a mineral's criticality depends on both its <u>importance in use</u> (vertical axis) *and* <u>supply risk</u> (horizontal axis).

3. The <u>greater the difficulty, expense, or time it takes to find and acquire a satisfactory mineral substitute</u> for a restricted mineral, the more critical that mineral is to a specific application or product—or, <u>the greater the impact of a mineral supply restriction</u>.

Conclusions (cont.)

4. When employing the matrix, the time frame must be established: short-, medium-, and long-term factors can affect the supply risk.

Over the short to medium term, restrictions may be due to:

- significant increase in demand;
- thin (or small) markets;
- concentration of production;
- production predominantly as a byproduct;
- lack of available scrap or infrastructure for recycling.

Over the long term, mineral availability is a function of investment and development of new supply related to five factors:

- geologic;
- technologic;
- environmental and social;
- political;
- economic.

Conclusions (cont.)

5. <u>Import dependence by itself is not a complete indicator of supply risk</u>.

- import reliance may be good for the U.S. economy if an imported mineral has a lower cost than domestic alternative;
- other factors must also be present (e.g. monopoly power, political instability, significant growth in foreign supplier's domestic demand).

6. Of the 11 minerals or mineral families the committee examined, those that exhibit the <u>highest degree of criticality</u> at present are:

- platinum group metals (automotive catalysts; fertilizers; petrochemicals);
- rare earth elements (automotive catalysts; permanent magnets; TVs; PC monitors);
- indium (flat-panel displays);
- manganese (hardening metal in various steels);
- niobium (alloy in high-strength, low-alloy and stainless steels; superalloy in aircraft engines).

Conclusions (cont.)

7. Decision makers need continuous, unbiased and thorough minerals information provided through a federally funded system of information collection and dissemination.

8. The USGS Minerals Information Team at present does not have sufficient authority, autonomy, and resources to appropriately carry out its data collection, dissemination, and analysis.

9. More complete information needs to be collected, and more research needs to be conducted, on the full minerals life cycle.

Dissemination and Impacts

- **Dual press release (National Academies), also picked up by a number of wire services (national and regional; an AP story was reproduced through more than 80 other outlets).**

- **Additional briefings requested from (and given to):**
  - **Committee on Earth Resources meeting (joint with Stockpile study)**
  - **Mitsui group (business consortium from Japan, visiting DC;**
  - **Industrial College of the Armed Forces (National Defense University**
  - **Mining Centre, Catholic University of Chile (Santiago)**
  - **Association of American State Geologists (joint with Stockpile study)**
  - **U.N. Environment Programme (Brussels)**

- **Reports cited in House floor debate on Mining Law Reform**

- **U.S. Geological Survey Mineral Resources Program established new quarterly report of mineral statistics**

Links to NAS Reports

http://www.nap.edu/catalog.php?record_id=12034 (crit mins)

http://www.nap.edu/catalog.php?record_id=12028 (stockpile)

THANK YOU

Statement of Task

Understanding the likelihood of disruptive fluctuation in the supply of critical minerals and mineral products for domestic applications, and making decisions about policies to reduce such disruptions, requires thorough understanding of national and international mineral sources, mineral production technology, the key uses of minerals and mineral products in the United States economy, and potential impediments to the mineral supply.

This study will:

1. **Identify the critical minerals** and mineral products that are essential for industry and emerging technologies in the domestic economy.
2. **Assess the trends in sources and production status** of these critical minerals and mineral products worldwide.
3. **Examine the actual or potential constraints**, including but not limited to geologic, technologic, economic and political issues, **on the availability of these minerals** and mineral products for domestic applications.
4. **Identify the impacts of disruptions in supply** of critical minerals and mineral products on the domestic workforce and economy.
5. **Describe and evaluate the current mineral and mineral product databases** and other sources of mineral information available for decision making on mineral policy issues.
6. **Identify types of information and possible research initiatives that will enhance understanding of critical minerals** and mineral products in a global context.

Report Structure

- Chapter 1 establishes methodology of the ‘criticality matrix’:

  -A critical mineral is both important in use (few if any substitutes) and subject to supply restriction; applies to uses across civilian, industrial, and military sectors.

  -A strategic mineral is narrower in scope, and relates to national security or military needs or requirements during national emergencies.

- Chapter 2 develops importance in use:

  -Mineral substitution depends on chemical and physical properties;

  -Importance in use is dynamic—changing with technology;

  -For a particular mineral, importance in use varies among different applications;

  -Examples from four industry sectors (automotive, aerospace, energy, and electronics).

- Chapter 3 addresses the availability and reliability of supply:

  -Consider time scales (short through long term)

  -Geologic, technical, social & environmental, political, economic factors

  -Primary (ore) and secondary (recycled) supplies

Report Structure

- Chapter 4 evaluates the criticality of specific minerals:
  -11 minerals were selected for analysis by the committee to represent a range of critical situations: Copper, gallium, indium, lithium, niobium, manganese, platinum group metals, rare earth elements, tantalum, titanium, vanadium.
- Chapter 5 discusses minerals information collection
  -Mineral data and the federal statistical program
  -Critical mineral information sources
  -Data, research, education and training needs
- Chapter 6: Conclusions and Recommendations

- Concurrent study conducted by the National Materials Advisory Board to assess the need for the National Defense Stockpile. Their report 'Managing Materials for a 21st Century Military' will be released together with this report.

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Study Schedule

- Three meetings (December 2006; March, May, 2007)
- December 2006 – Committee and sponsors; discussion
- March 2007 – Main information gathering meeting
  - two days, four panel sessions
  - external panelists from private, federal, research sectors
- May 2007 – Writing meeting
- August 2007 – Report submitted to review
- September 2007 – Report approved for publication