

# **Rare Earth Elements (REE), Conflict Metals and Supply Chain Security**

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# REE Materials Scarcity/Supply Chain Security

- What are Rare Earth Elements?
- What are some uses?
- What are some concerns?
- Similar issue: Conflict Metals
- What can be done to reduce the supply chain risk?



Worker in RE mine in China - Reuters

- Sources: Reuters; Bloomberg; et al; *Rare Earth Elements: The Global Supply Chain*; Marc Humphries; *Rare Earths in Selected US Defense Systems*; James Hedrick, USGS

Table 1. Names and symbols of the REE

La	lanthanum	Tb	terbium
Ce	cerium	Dy	dysprosium
Pr	praseodymium	Ho	holmium
Nd	neodymium	Er	erbium
Pm	promethium	Tm	thulium
Sm	samarium	Yb	ytterbium
Eu	europium	Lu	lutetium
Gd	gadolinium	Y	yttrium

# Rare Earth Elements – REE/REO/REM

- Lanthanum
- Cerium
- Praseodymium
- Neodymium
- Promethium
- Samarium
- Europium
- Gadolinium
- Terbium

**REE are actually not that rare! –  
What is rare is their presence in  
ores at concentrations that can be  
profitably mined and refined**



- Dysprosium
- Holmium
- Erbium
- Thulium
- Ytterbium
- Lutetium
- Scandium
- Yttrium

***They were originally described as rare  
because they were unknown in their  
elemental form and difficult to extract  
from ores...***



# Certain REE - Uses and Users

## REE and Uses

- **Neodymium, Praseodymium and Dysprosium**
  - High-strength NdFeB magnets
  - Miniaturization of electronic products
- **Lanthanum and Cerium**
  - NiMH batteries for hybrid and electric vehicles
- **Europium, Terbium and Yttrium**
  - Compact fluorescent light bulbs
  - Magnets (terbium)
- **Lanthanum**
  - Petroleum cracking catalysts
- **Cerium**
  - Water filtration



## Common Devices

- iPhones and BlackBerrys
- Clean energy technologies
- Advanced ceramics
- Computers and monitors
- DVD players
- Televisions
- Lighting and Lasers
- Fiber optics
- Glass polishing
- Superconductors
- Wind Turbines
- Solar Panels
- Catalytic Converters
- Hybrid and Electric Cars
- Defense Systems

# REE 101

- Users dependent on a low cost, secure REE supply chain
- 95-97% of the current REE supply is controlled by one producer
- Additional sources are being sought and developed
- Human health, environmental and social considerations are significant factors
- Alternatives, substitution and recycling are being considered



**Neodymium**  
*Bloomberg News*

**China froze all exports to Japan in Oct 2010, following a border dispute with Japan and Japanese detention of a Chinese fishing boat captain. (SustainableBusiness.com News)**

- **REE Ore is refined into REE materials:**
  - Powders, Oxides, Pure metal
- **Japan buys raw REE from China and processes into RE Materials**
- **US and Europe buy highly refined powders from China**
- **After holding up shipments to Japan, China halted shipment to Europe and US**
- **Prices have soared – in some case 10-100 fold in few years**

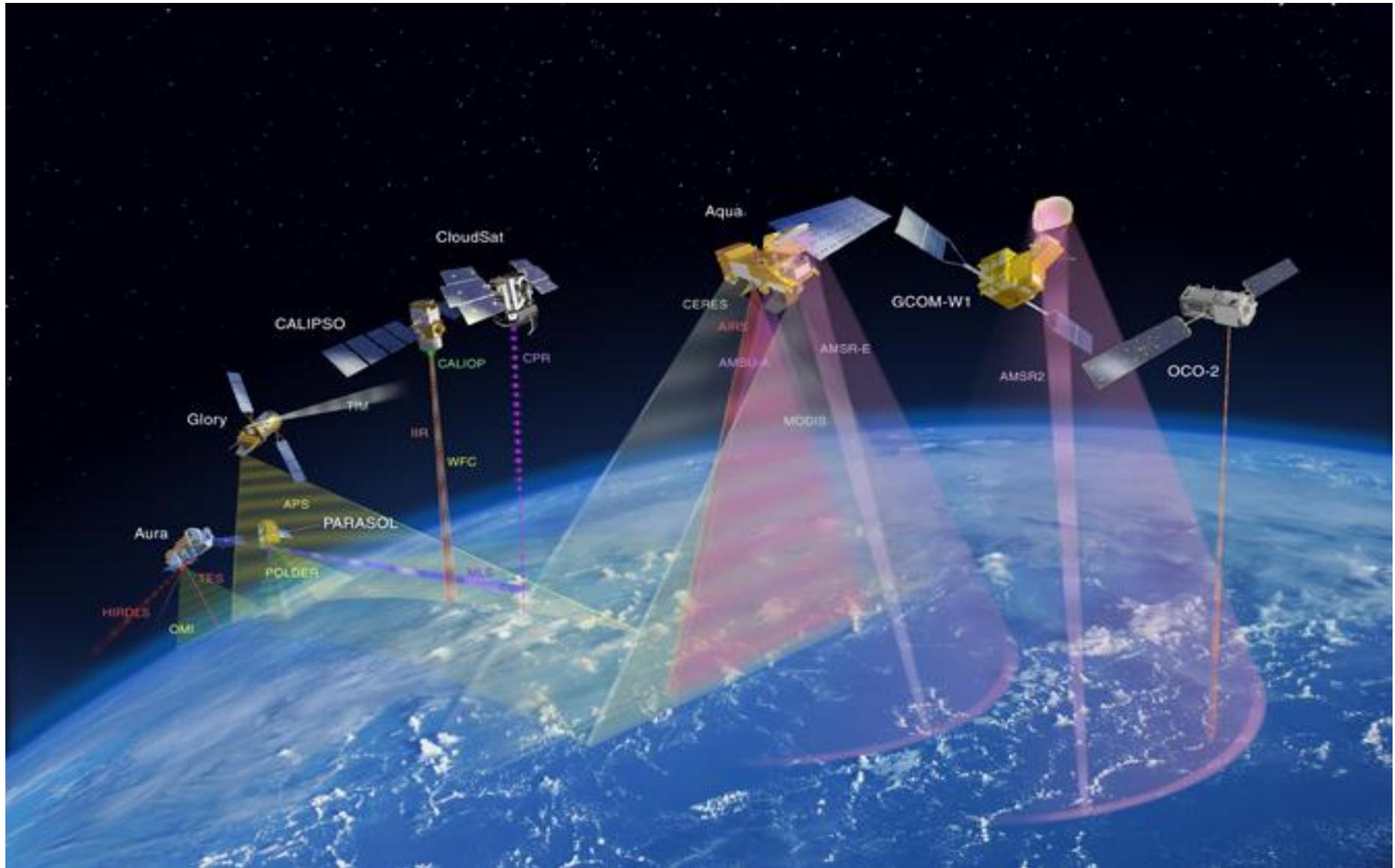


# Space Agency REE Materials and Equipment Supply Chain Uses and Challenges

- **Satellites**
- **Radar**
- **Lasers**
- **Propulsion Systems**
- **Computers**
- **Lighting**
- **Communications**
- **Coatings**
- **Renewable Energy**
- **Water Filtration**



# Satellites: Neodymium, yttrium and others



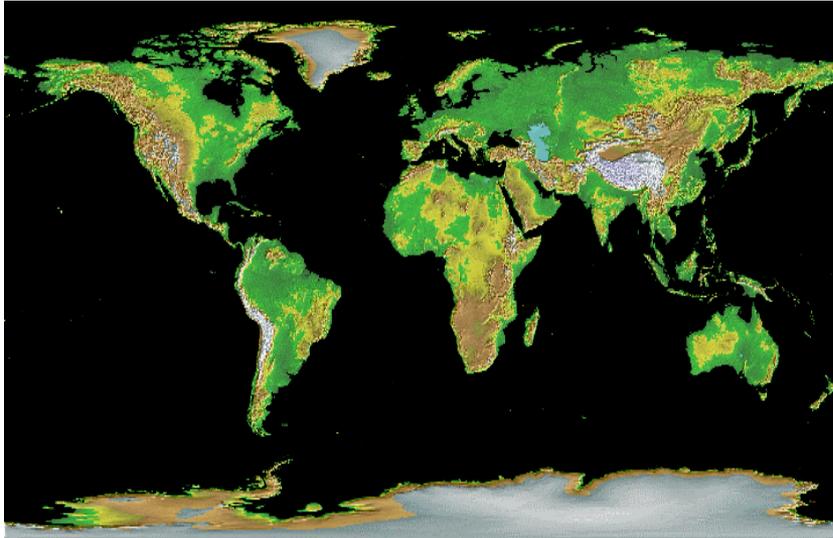
# Avionics: Europium fluorescents and phosphors



# Who Has a Stake in REE?

## Nations

- China
- Japan
- Europe
- India
- Brazil
- Russia
- Canada
- Vietnam
- Australia
- Malaysia
- Afghanistan
- United States
- Just about the whole developed - and developing - world...



## Organizations

- Space Agencies
- Defense Agencies
- Clean Energy Industry
- Manufactures: cell phones, electronics, wind turbines, batteries, vehicles and glass manufacturers
- Petroleum refining
- Petro-chemical companies
- Mining companies
- Computer companies

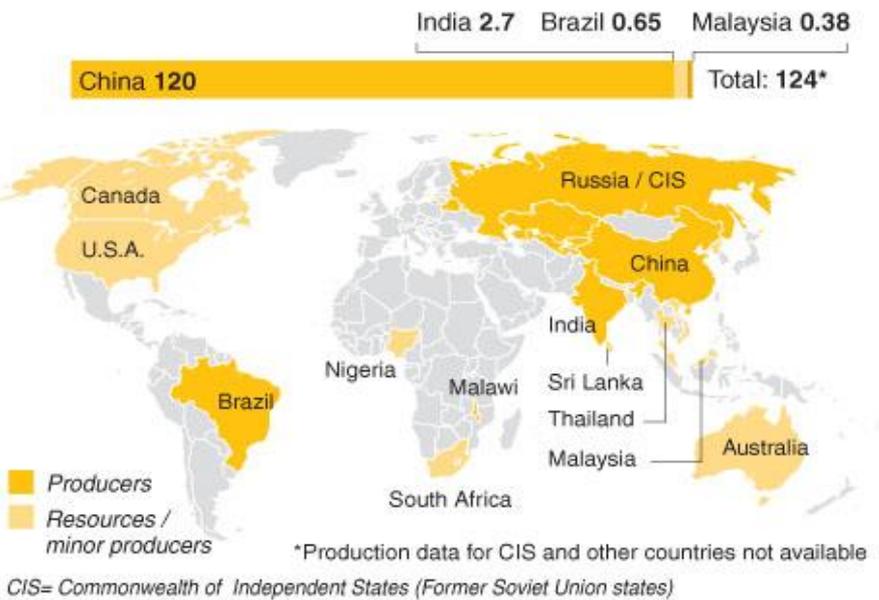
# RARE EARTH METALS

## WHAT IS IT?

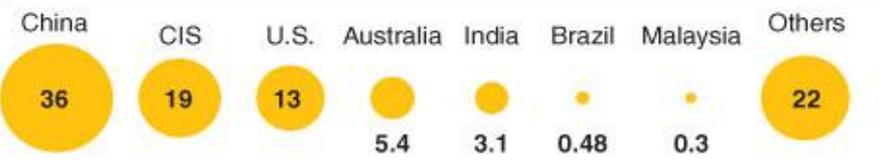


- ▶ Mineral group which contains 17 chemical elements; scandium, yttrium and 15 lanthanide elements
- ▶ Not as rare as the name implies, but is difficult to find in concentrations high enough for economical extraction
- ▶ Used in the production of many devices including LCD screens, computer chips, optical media, rechargeable batteries, mobile phones, magnets, and car components

## 2009 PRODUCTION in thousand metric tons



## WORLD RESERVES in million metric tons

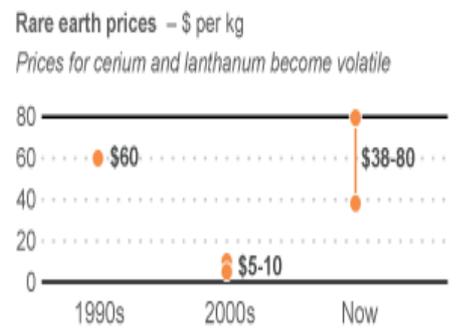
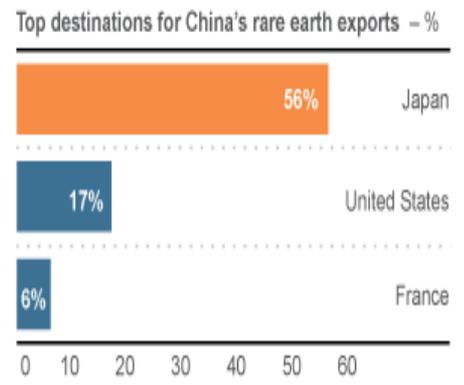
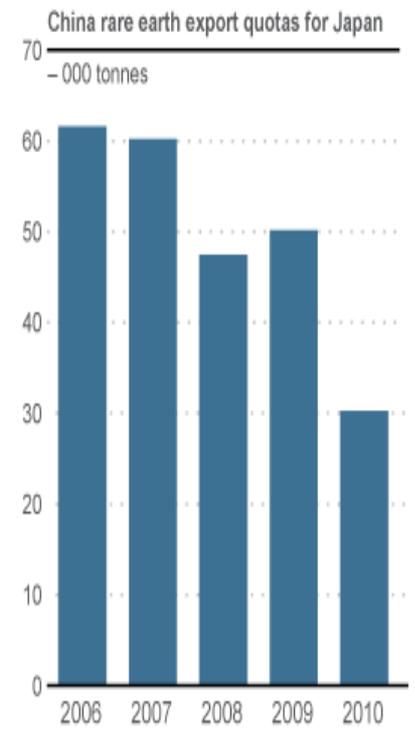


Japan and the U.S. imports the largest amount of rare earth metals for their tech and auto industries  
 Source: USGS



# Rare Earth Distribution, Production and Pricing

## Rare earth elements



Source: China Ministry of Commerce, Japan's trade ministry, Japan Society of Newer Metals

Reuters graphic/Christine Chan



08/10/10



# Heavy REE and Material Criticality

**Rare Earth Elements**

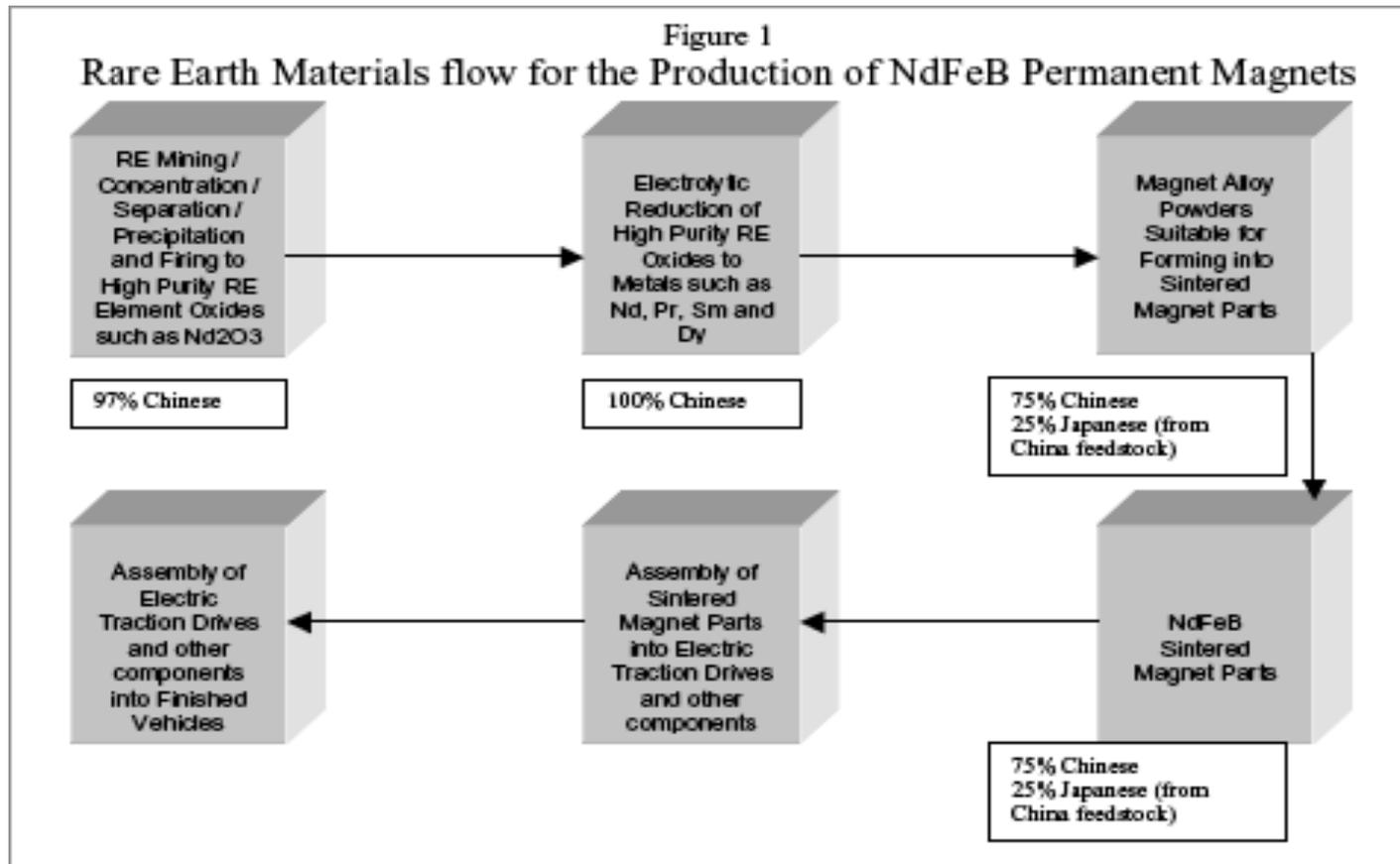
<b>La</b> 57	<b>Ce</b> 58	<b>Pr</b> 59	<b>Nd</b> 60	<b>Pm</b> 61	<b>Sm</b> 62	<b>Eu</b> 63	<b>Gd</b> 64	<b>Tb</b> 65	<b>Dy</b> 66	<b>Ho</b> 67	<b>Er</b> 68	<b>Tm</b> 69	<b>Yb</b> 70	<b>Lu</b> 71	<b>Y</b> 39
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Lanthanides

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	An	Lr														

- Light REE are more prevalent than Heavy REE (higher atomic numbers) and HREE are currently only available from China
- A location in Canada is estimated to have 25-39% of the HREE in the world
- US DOE report describes 5 REEs as “Critical” in the short and medium term
- Dysprosium (most critical/rare); Europium; Neodymium; Terbium (rare); Yttrium; Indium (only in short term)

# Example Rare Earth Magnet Supply Chain



# What is Difficult About REE?

- **Low concentrations are difficult to separate from ores**
- **Difficult to refine, concentrate and purify**
- **Environmentally problematic**
- **Extraction and refining typically generates radioactive (thorium) and acidic, metal-bearing wastes**



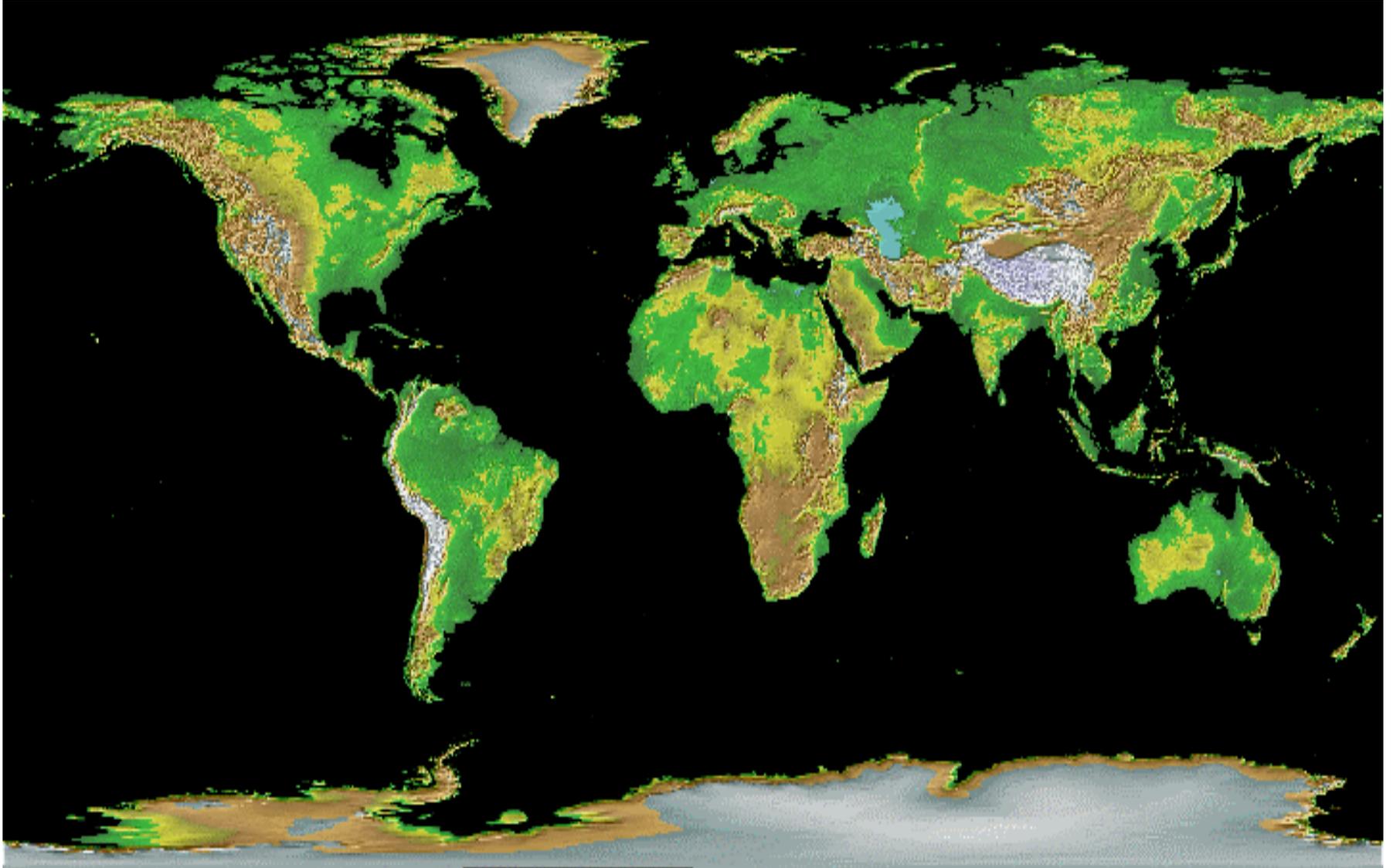
# REE Environmental Issues: Learning from China

- At Baotou, ore processing waste is pumped into a 4 square mile reservoir surrounded by an earth embankment four stories high
- The reservoir is 100 times the size of the waste pond in Hungary that collapsed sending caustic sludge through villages killing 9 people
- There is a spreading plume with detectable radioactivity in the groundwater
- Plume is migrating 300 yards a year toward the Yellow River, seven miles away, that supplies drinking water to much of northern China
- Southern China affected by acid treatment of REE. *Bloomberg/Reuters*



*Baotou, China Bayan Obo mining region in Inner Mongolia - China's main REE mining and production center*

# What is Being Done?

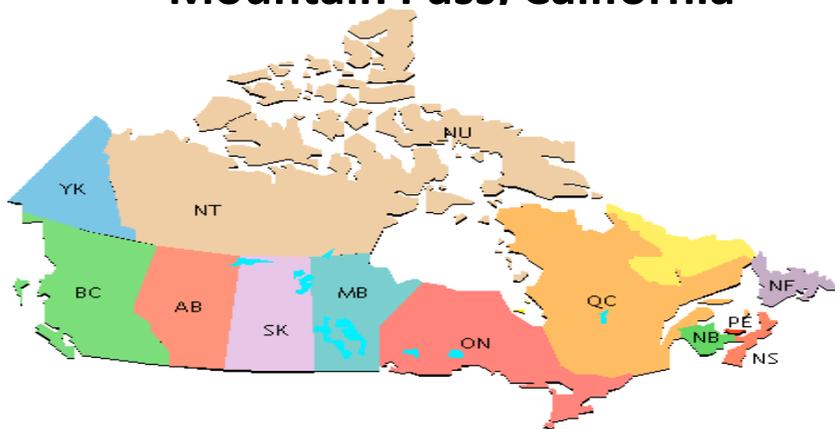


# Reports and Legislation in the US

- A report by US DOD on military use of REE reportedly says there is no threat to production of military equipment
- Some members of the US Congress disagree
- Various bills are under consideration by the US Senate and House of Representatives to:
  - Expedite permitting
  - Establish a REE Task Force
  - Support domestic production
  - Establish a federal working group to study strategic needs
  - Create a REE strategic national stockpile
  - Evaluate international trade practices and facilitate loan guarantees for U.S. suppliers
- A DOE document has a plan to boost production of rare metals and identifies REE “criticality”

# Mines Under Development Outside China

- **Great Western Minerals**
  - Steenkampskraal, South Africa (projected at 2,700 tons)
- **Avalon Rare Metals**
  - Nechalacho, Canada
- **Lynas Corp**
  - Mount Weld, Australia
- **Arafura Resources**
  - Nolans, Australia
- **Molycorp**
  - Mountain Pass, California



# **A Related Issue: Conflict Minerals**

- **Gold and the 3Ts: Tin, Tantalum, Tungsten**
  - Tin – solder and circuit boards
  - Tantalum - portable electronics and high-speed processors
  - Tungsten - cell phone vibration alert
  - Gold – jewelry and electronics
- **Concerns driven by wars in the Democratic Republic of the Congo (DRC) and worth hundreds of millions of \$\$ per year involving**
  - Rebel groups
  - Militias
  - Criminal networks
  - Slave labor

# **Conflict Minerals**

- **The US Financial Stability Act of 2010 requires American companies to submit annual report to Securities & Exchange Commission disclosing if their products contain tin, tantalum, tungsten or gold sourced from the DRC or adjoining countries**
- **“Adjoining countries” include:**
  - **Uganda; Rwanda; Burundi; Tanzania**
  - **Zambia, Angola, Republic of Congo, Sudan and Central Africa Republic**
- **The “Enough Project” engaged companies to demonstrate their materials are “conflict-free”**

# Conflict Minerals

- **“Enough Project” list of most responsive companies:**
  - HP
  - Intel
  - Motorola
  - Nokia
  - Microsoft
  - Dell
- **Followed by: RIM, Acer, Apple, Phillips, Samsung, LG, Sony Ericsson, IBM, Lenovo, et al...**
- **The Enough Project continues their work (see their website at: [www.enoughproject.org](http://www.enoughproject.org))**

# Significant Challenges

- **Recycling?**
- **Substitution?**
- **Concentration and purity of ores?**
- **HREE vs LREE?**
- **Availability of Refinement Technology?**
- **Consideration of REEs individually – not as a group?**



**Molycorp Mountain Pass Mine;  
Mountain Pass, California**

# What Can Organizations Do to Reduce REE Risk?

- Specify REE uses and define needed types and amounts
- Define and analyze the supply chain - current sources, costs, vulnerabilities and risks
- Identify/evaluate alternative sources
- Develop risk mitigation plans to secure and diversify the supply chain

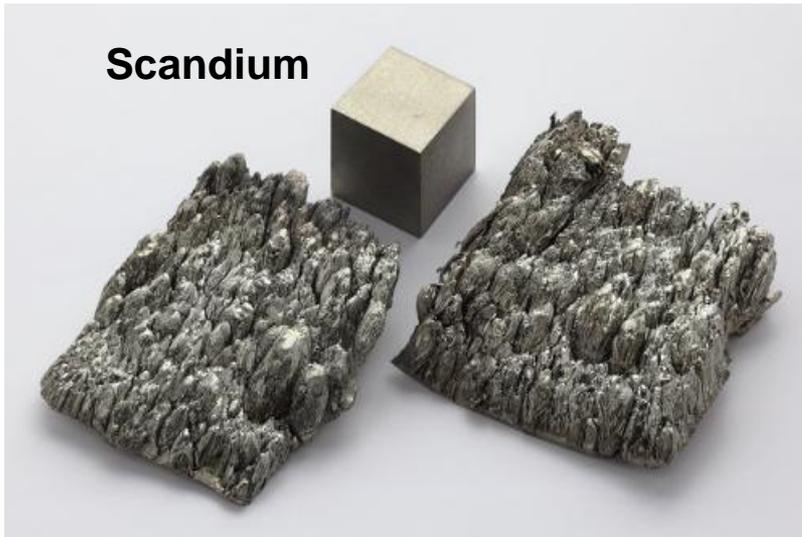


- Invest in R&D and consider non-REE substitutes, alternatives, recycling
- Evaluate performance contracts
- Integrate with systems design
- Consider developing resource/supply networks
- Consider developing resource/supply partnerships with organizations of similar interest (e.g. Space)



# Questions? Comments?

Scandium



**Rare Earth Elements**

La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Y
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	39

Lanthanides

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	An	Lr														



**Rare Earth Elements (REE)  
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**November 2011**

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