



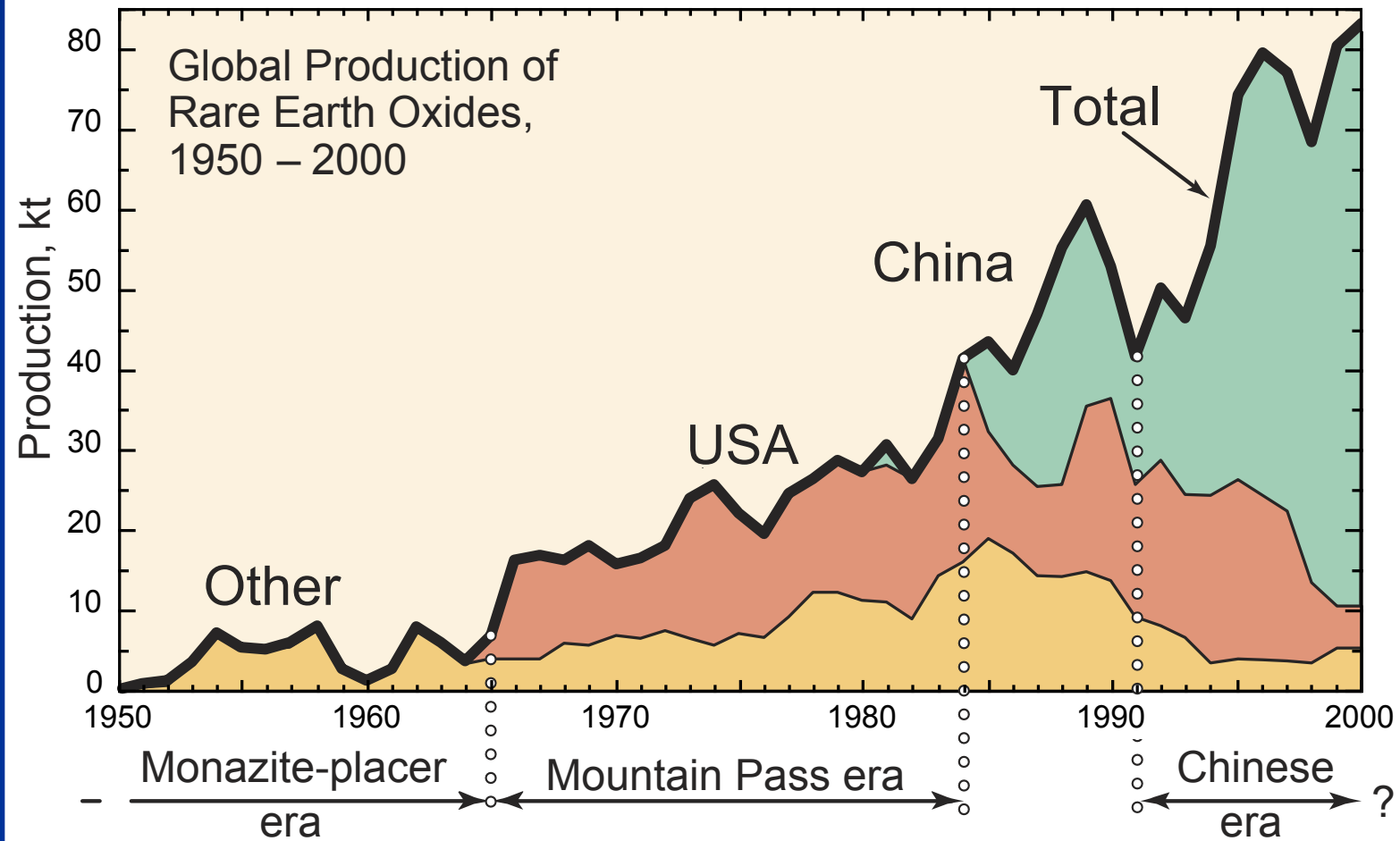
Rare-Earth Industry Overview & Defense Applications

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U.S. Geological Survey
Reston, VA
18 February 2005

U.S. Department of the Interior
U.S. Geological Survey

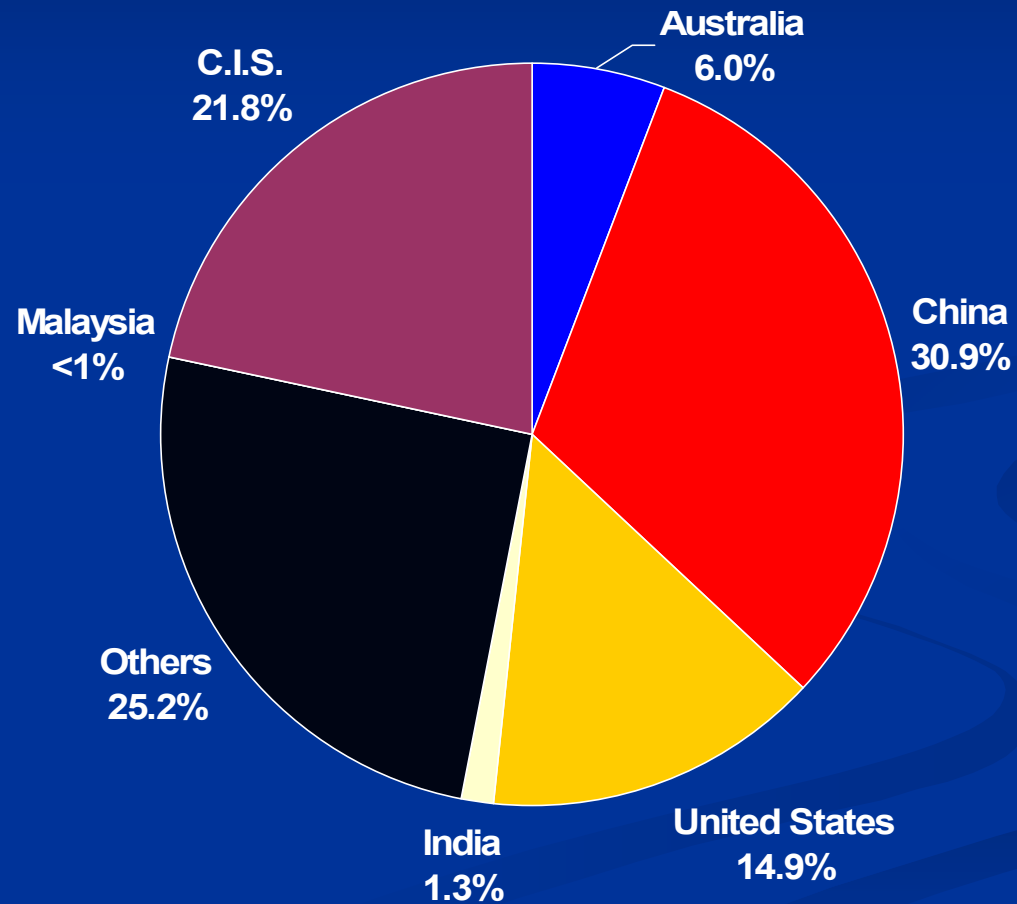
Note: the following presentation is an excerpt from the original

REE Production Trends



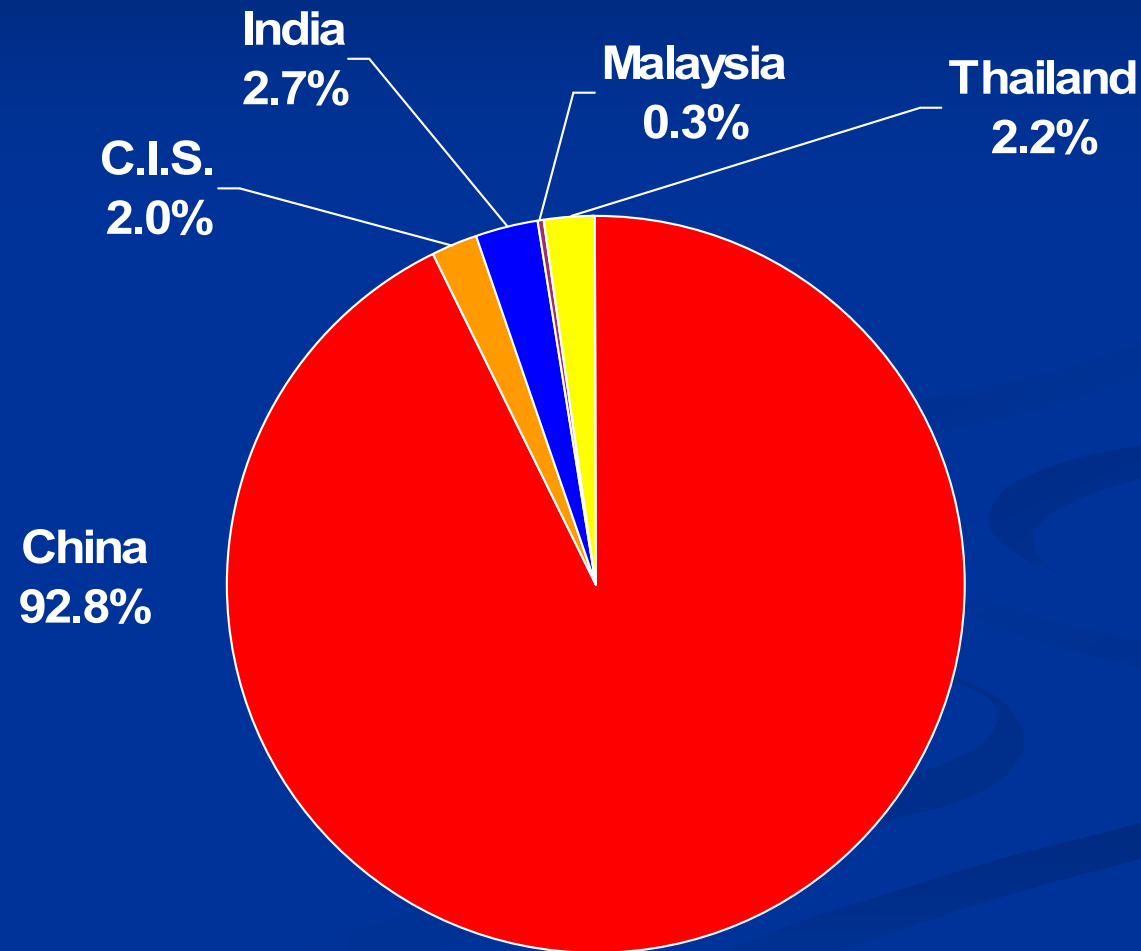
REE Mineral Reserves

88 million tons contained REO



REE Mineral Production 2003

99,100 metric tons contained REO



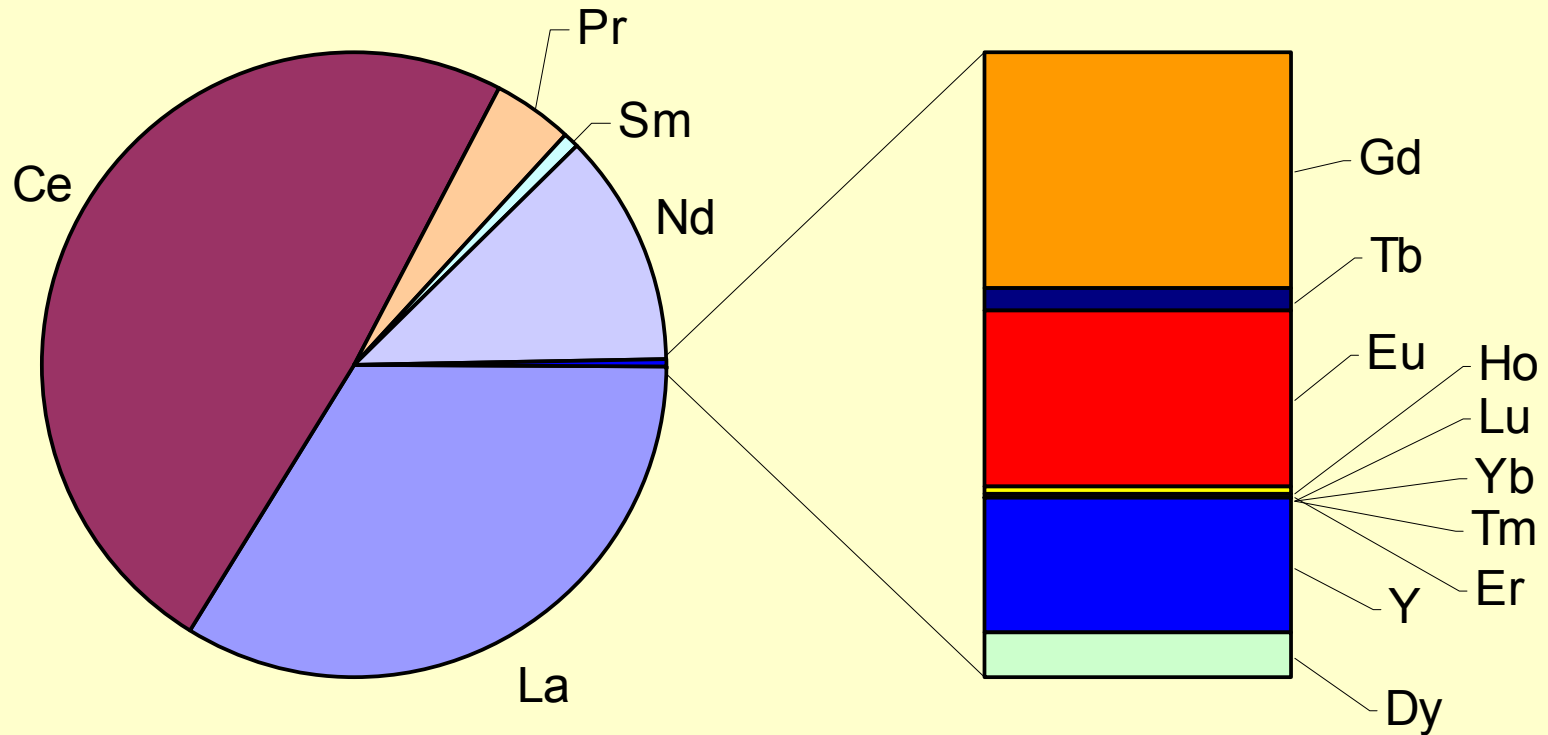
Rare Earth Ores

- Bastnäsite-(Ce) $(\text{Ce, La, Nd, Pr})(\text{CO}_3)\text{F}$
- Monazite-(Ce) $(\text{Ce, La, Nd, Th})\text{PO}_4$
- Xenotime-(Y) YPO_4
- Loparite-(Ce) $(\text{Ce, Na, Ca})(\text{Ti, Nb})\text{O}_3$
- Lateritic ore REE ions absorbed on clay
 - ion absorption clay Y-rich
 - ion absorption clay La, Nd-rich

Bastnäsite

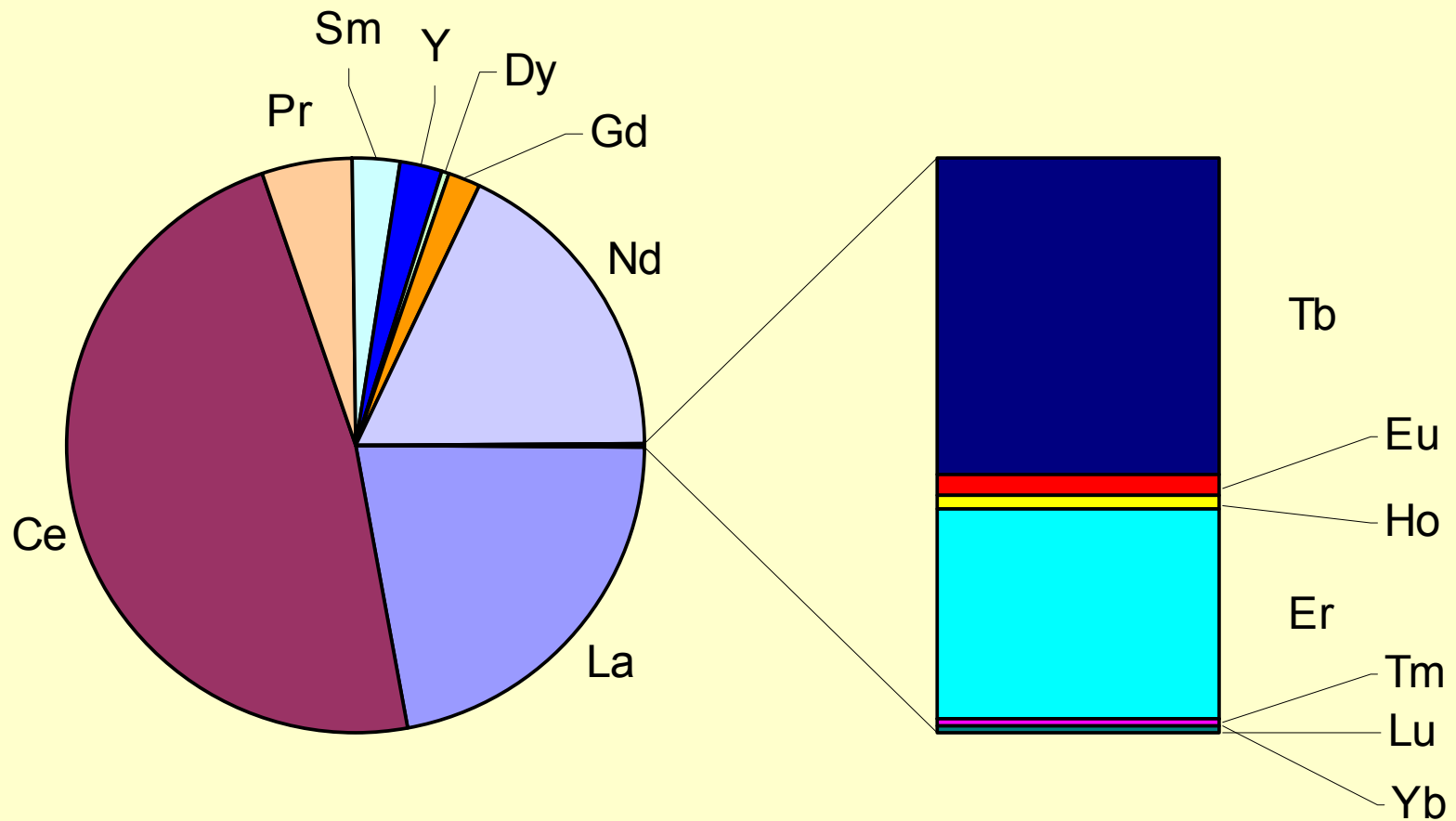
Mountain Pass, CA

Weight Percent of Total Recovered REE:
Bastnasite (Mountain Pass, CA)



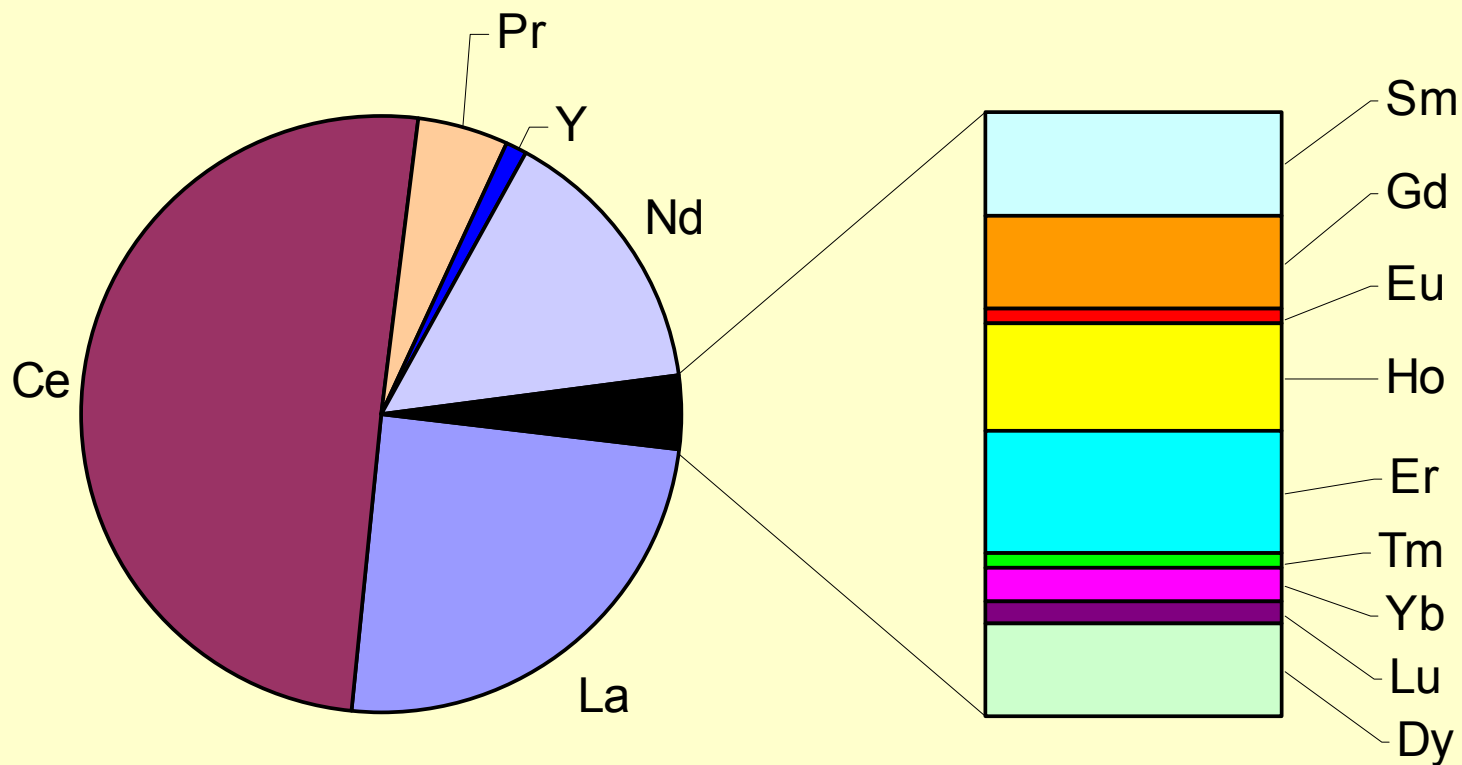
Monazite Australia

Weight Percent of Total Recovered REE:
Monazite (Australian)



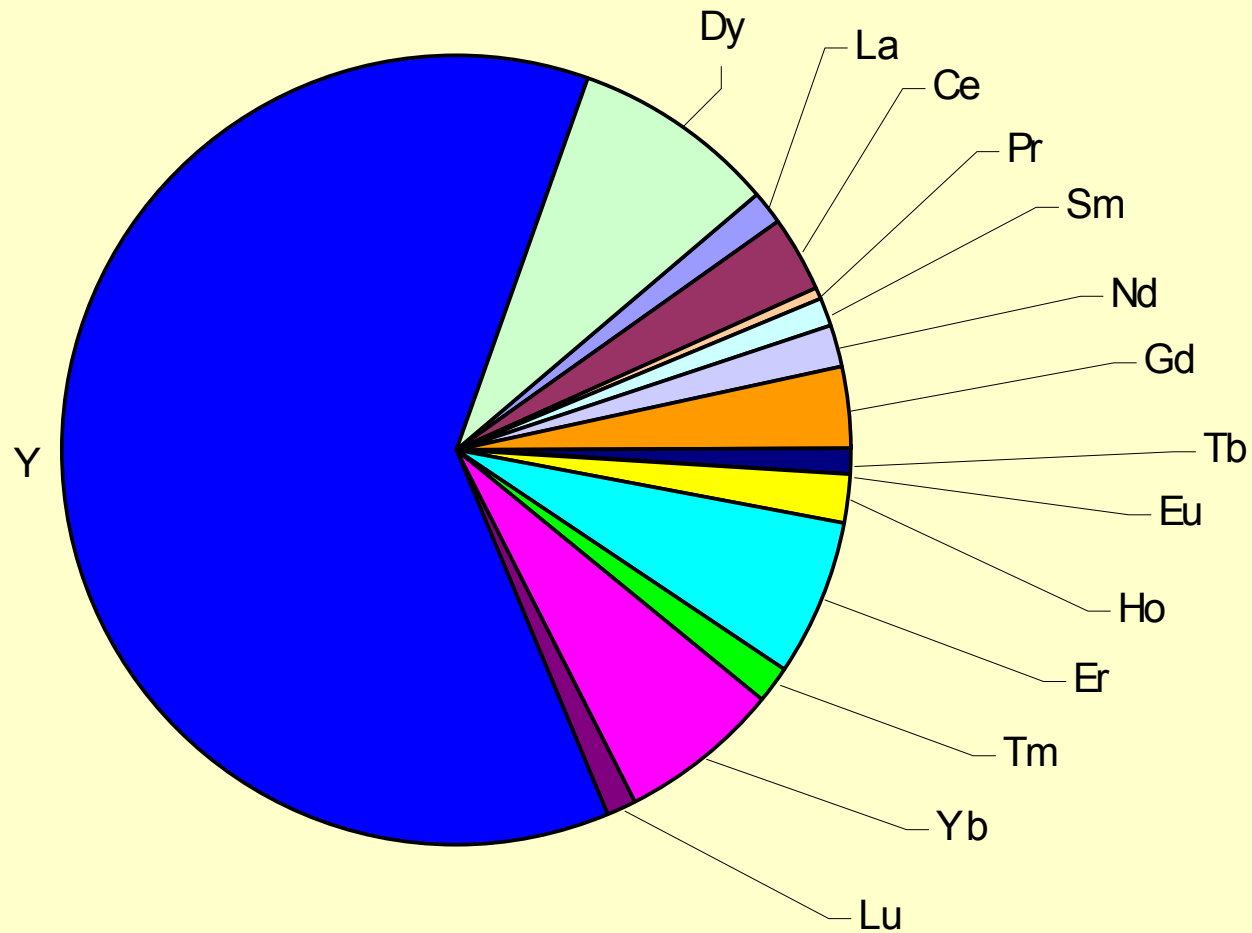
Loparite Russia

Weight Percent of Total Recovered REE:
Loparite (Russia)



Xenotime Malaysia

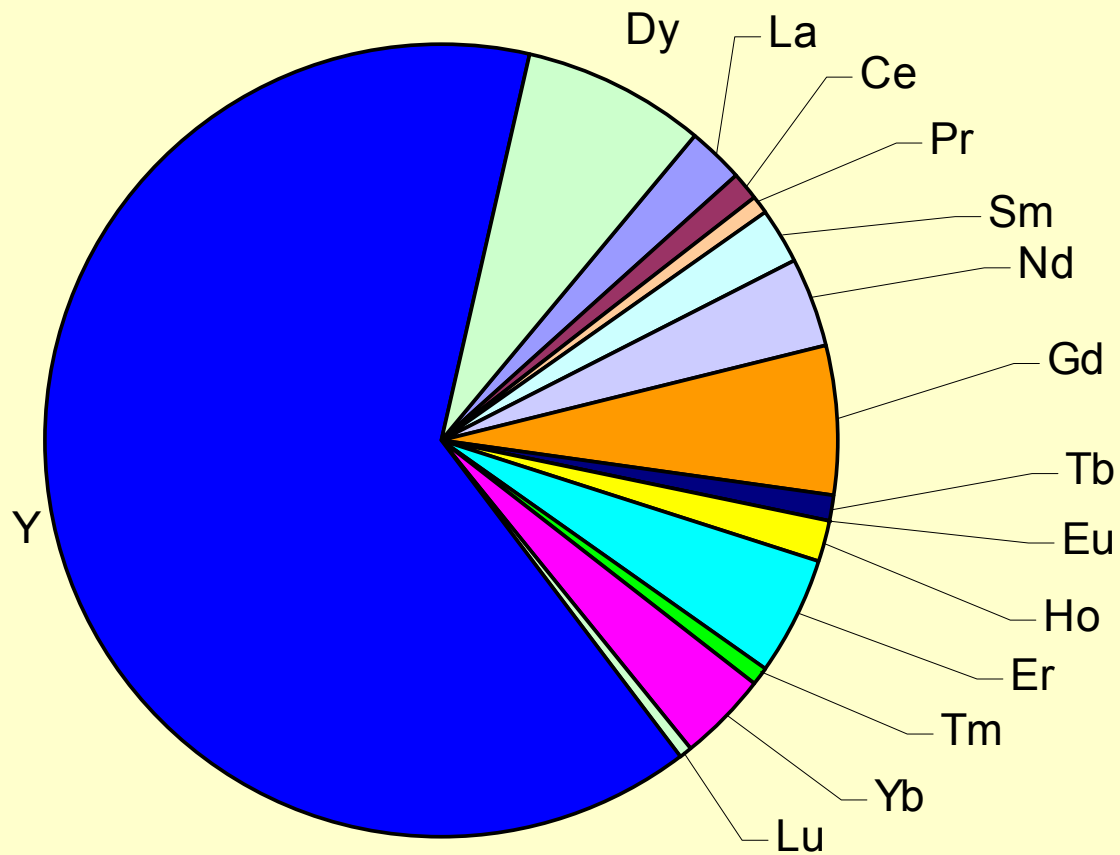
Weight Percent Of Total Recovered REE:
Xenotime (Malaysian)



Lateritic Ore

Longnan, Jiangxi Province, China

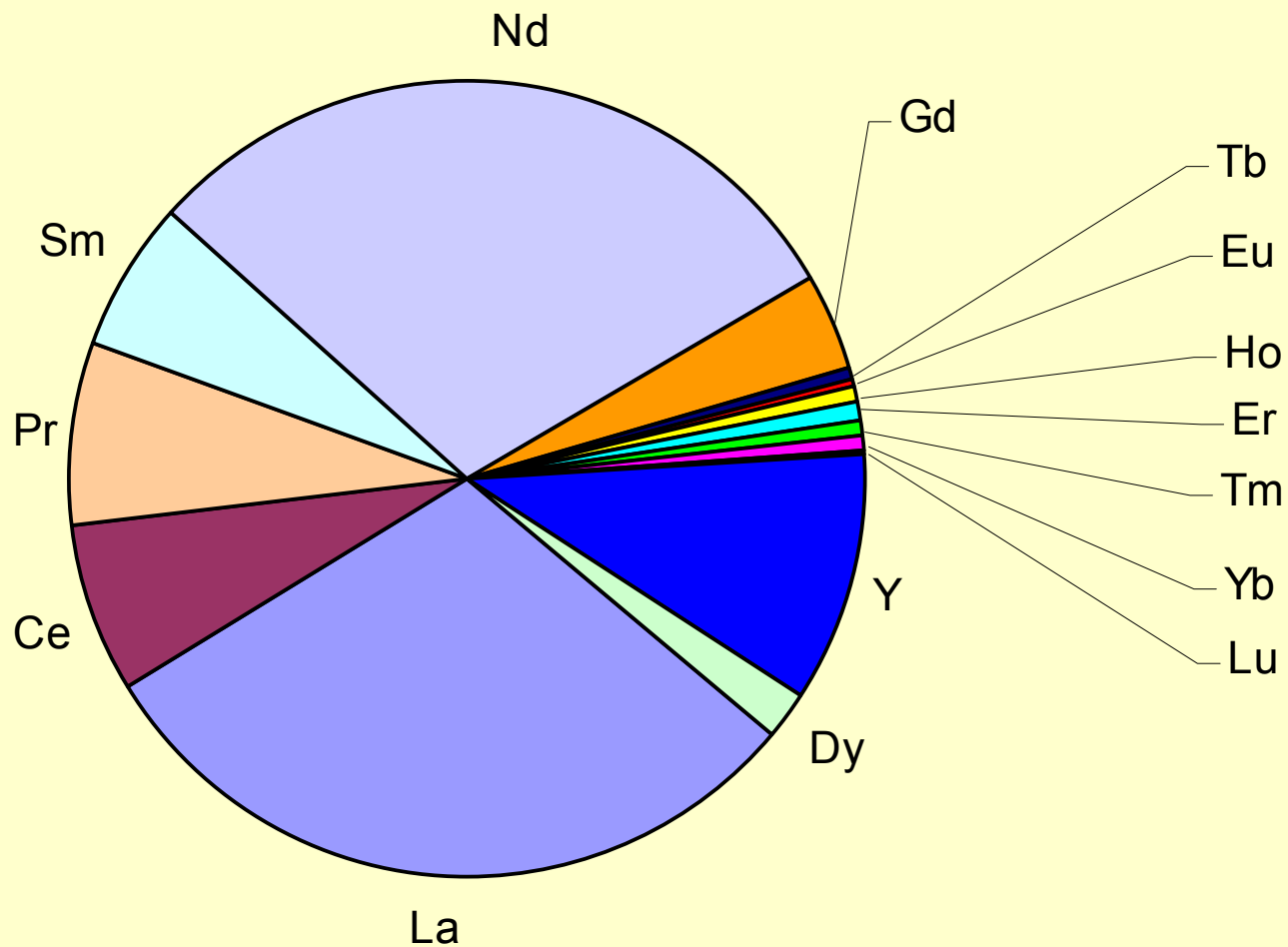
Weight Percent of Total Recovered REE:
Longnan Lateritic Ore (China)



Lateritic Ore

Xunwu, Jiangxi Province, China

Weight Percent of Total Recovered REE:
Xunwu Lateritic Ore (China)



Principal Rare-Earth Deposits

■ Bastnäsite

- Mountain Pass, CA, USA
- Bayan Obo, Inner Mongolia, China
- Mianning, Sichuan Province, China
- Weishan Lake, Shandong Province, China

■ Monazite

- Kerala State, Tamil Nadu State, and Orissa State, India

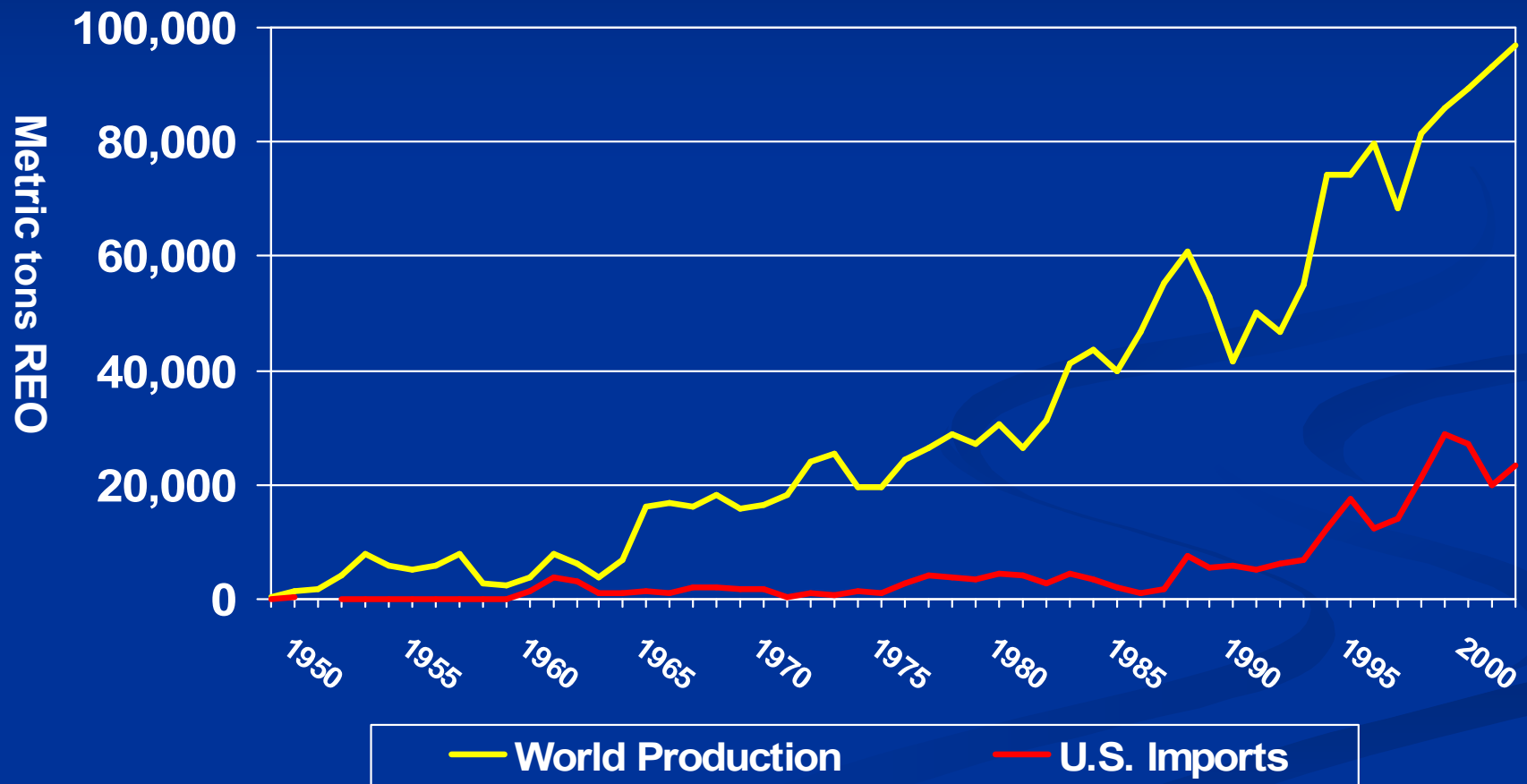
■ Lateritic ion-absorption clay

- Xunwu, Jiangxi Province, China
- Longnan, Jiangxi Province, China

■ Loparite

- Lovozero, Kola Peninsula, Russia

Rare Earth World Production and U.S. Imports





AIM -9X Sidewinder

AIM-54A Phoenix



AIM-120 AMRAAM



AIM-120 AMRAAM missile launch





BGM-109 Tomahawk Cruise missile



**Smart
bombs
(JDAM)
Joint
Direct
Attack
Munitions**



Nd:YAG designator-rangefinder laser



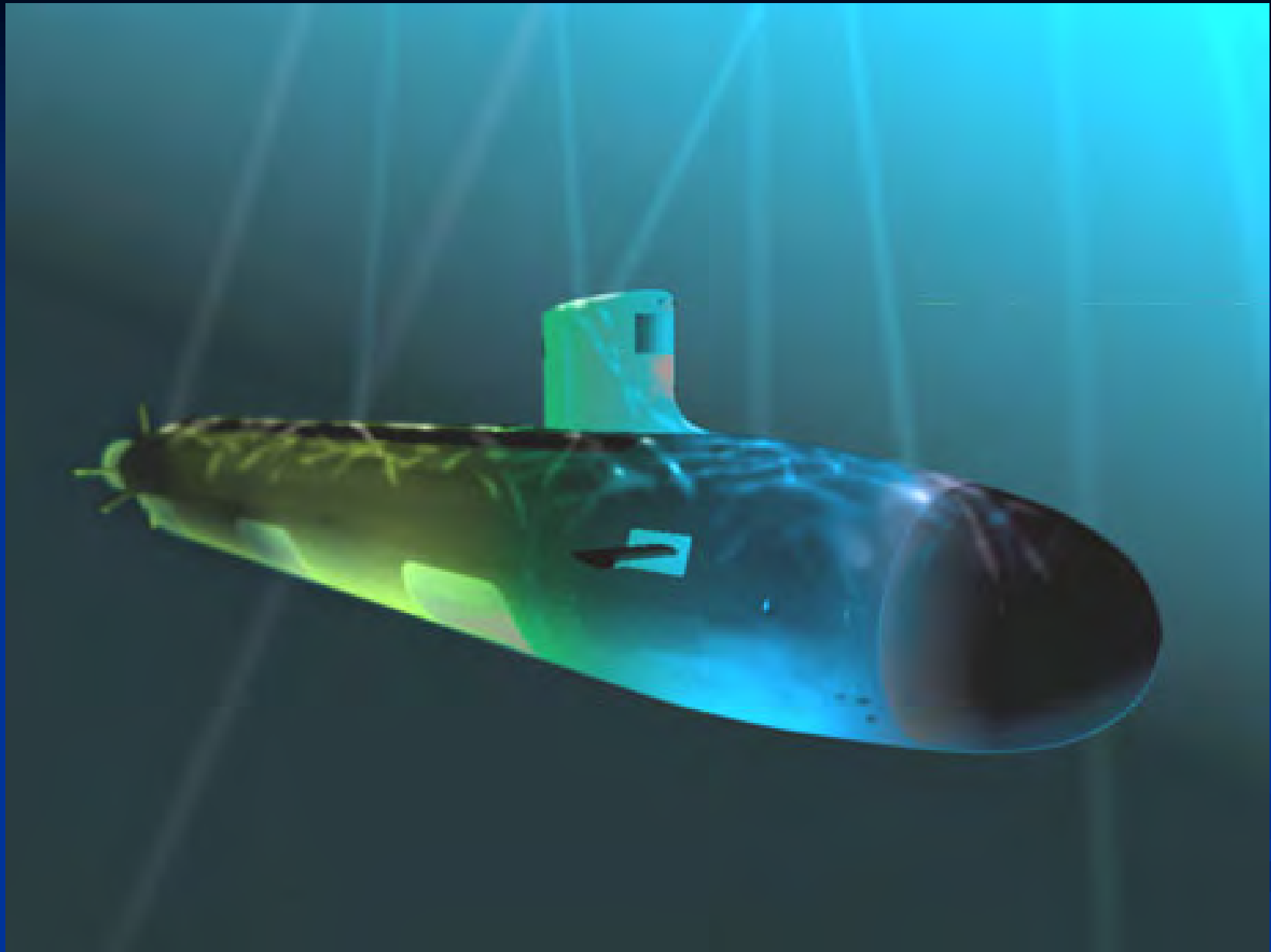
**Laser targeting system on
Abrams M1A1 tank**



F-15 with yttria-stabilized zirconia



F-16 Avionics with REE phosphors



Sonar transducers for submarines



Radarsurveillance

Electronic Warfare

- ELINT – Electronic Intelligence
- ECM – Electronic Countermeasures
 - Support Jamming
 - Self-Protect Jamming
- ESM – Electronic Surveillance
- Use Yttrium Iron Garnets (YIG) and Yttrium Gadolinium Garnets (YGG)

Ferrite-Enabled Defense Systems

- **Phased-Array Radars**

Patriot, Aegis, B-1B, Joint STARS, SPQ-9B

- **Communication Satellites**

DSCS III, MILSTAR, Advanced EHF, Classified

- **Communication Systems**

F-22 Intra-Flight Data Link, Dark Star UAV Data Link

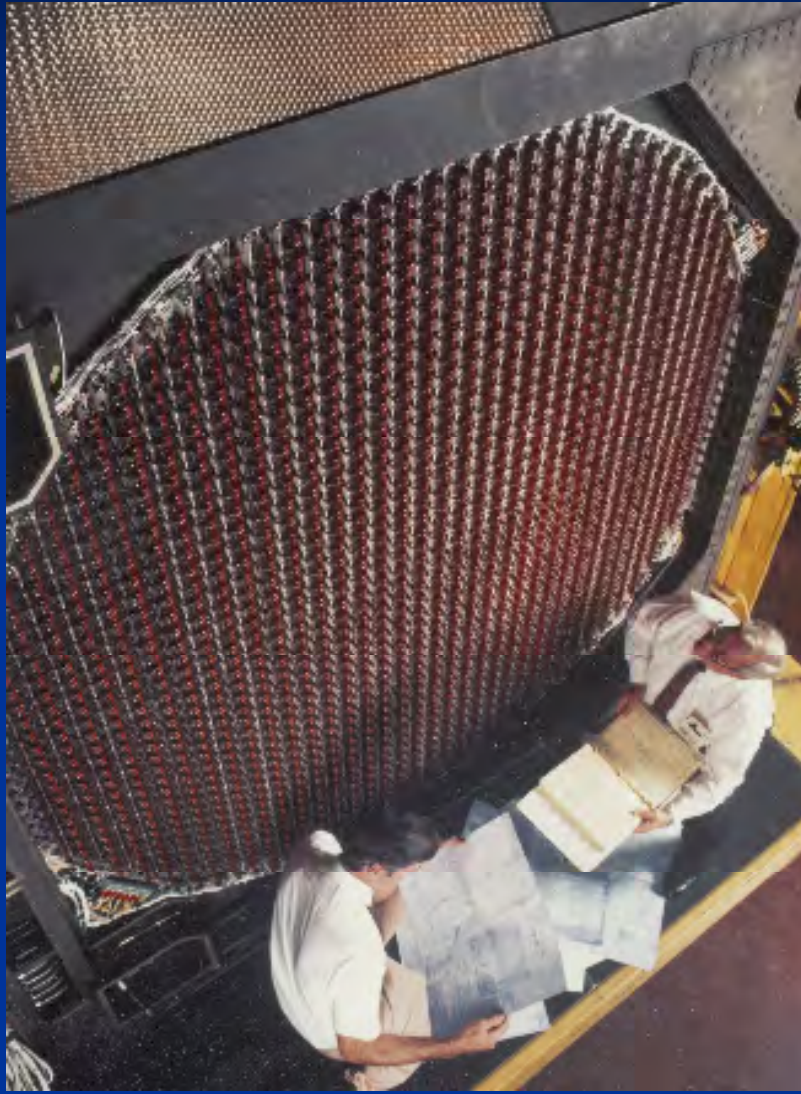
Potential JSF, UCAV, etc.

- **ECM Systems**

ALQ-172 (B-52, AC-130), ALQ-178 (F-16)

ALQ-211 (AH-64D, MH-47, MH-60, CV-22)

Patriot phased-array defense system





**Rare Earths are used in Defense
every second...24/7**