

# USMMA

## Defense Supply Chain Assessment Select Systems Employing Rare Earths



## DISCLAIMER

The USMMA is currently performing an on-going assessment of the Defense Department's rare earth supply chain. The following slides represent select systems known to contain components that utilize rare earth elements. The uses cited include rare earth permanent magnets and many other uses.

This assessment is not comprehensive. There may be additional systems not listed here with components that utilize rare earth. Likewise, each system listed may contain additional components that utilize rare earths. The USMMA welcomes any comments, suggestions, or contributions to this report. The USMMA makes no assurances or warranties regarding any information contained within this document.

To contribute to this on-going assessment please send an email to [info@jagreenandco.com](mailto:info@jagreenandco.com)

# Rare Earth Supply Chain<sup>+</sup>

Oxides	Metals, Alloys & Powders	Phosphors	Magnets	
Lynas – exp. 2011 Australia	Santoku Corporation <i>Japan/ US</i>	Rhodia <i>US, France</i>	<u>Distributors/ Fabricators*</u>	<u>Manufacturers**</u>
Molycorp – exp. 2012 US	Shin Etsu <i>Japan</i>		Magnetic Component Engineering, Inc. <sup>1, 2</sup> <i>US</i>	Electron Energy Corporation <sup>1</sup> <i>US</i>
Japan Oil, Gas and Metals National Corp <i>Japan</i>	Great Western Minerals Group/ Less Common Metals <i>Canada/ UK</i>		Dexter Magnetic Technologies <sup>1, 2</sup> <i>US, UK, China</i>	Thomas and Skinner <sup>3</sup> <i>US</i>
<b>China produces 97% of world supply</b>	CAS Key Laboratory of Rare Earth Chemistry and Physics <i>China</i>		Allstar <sup>2</sup> <i>US</i>	Arnold Magnetic Technologies <sup>1, 3</sup> <i>US/ Switzerland</i>
Sichuan Mianning Mining Co <i>China</i>	Neo Materials (Magnaquench) <i>China</i>		Quadrant <sup>1, 2</sup> <i>US</i>	Shin Etsu <sup>1, 2</sup> <i>Japan</i>
Jiangxi Copper <i>China</i>			Adams <sup>1, 2</sup> <i>US</i>	Vacuumschmelze GmbH/ Neorem <sup>1, 2/ 2</sup> <i>Germany/ Finland</i>
Baotou Steel Rare Earth <i>China</i>			Bunting <sup>1, 2</sup> <i>US</i>	Hitachi Metals <sup>1, 2</sup> <i>Japan</i>
Sichuan Hanxin Mining Industrial Co <i>China</i>			Integrated Magnetics <sup>1, 2</sup> <i>US</i>	Chengdu Magnetic Material Science & Technology Company <sup>1</sup> <i>China</i>
<p><b>*Distributor/Fabricators</b> typically import overseas material and resell it to domestic customers. Many merely pass product through from manufacturers to end-users. Others do some minimal grinding. The more sophisticated of the lot will fabricate higher value components using imported magnets.</p> <p><b>**Manufacturers</b> typically create their own proprietary alloys, and either cast or sinter magnets from those alloys. Control over the quality of the alloys is an important distinction of this group, as they are not typically dependent on overseas material suppliers. In addition to cast and sintering capabilities, the magnet manufacturers also typically utilize heat treating processes, in order to further enhance the properties of the magnets. The magnet manufacturers generally maintain a full range of manufacturing capabilities, to enable them to manufacture all forms of custom designs and applications. Magnet manufacturers can also fabricate high value components utilizing the magnets they have made.</p> <p><sup>1</sup> Including Samarium Cobalt Magnets (SmCo)  <sup>2</sup> Including Neodymium Magnets (NdFeB)  <sup>3</sup> Plans to manufacture Neodymium Magnets (NdFeB)  <sup>4</sup> Plans to manufacture Samarium Cobalt Magnets (SmCo)                      +Examples, not an inclusive list</p>			Magnet Sales <sup>1, 2</sup> <i>US</i>	Zhejiang Tinnau Group <sup>1</sup> <i>China</i>
			Stanford Magnetics <sup>1, 2</sup> <i>US</i>	Ningbo Co-Star Material High Tech Co. Ltd <sup>1, 2</sup> <i>China</i>
			Dura magnetic <sup>1, 2</sup> <i>US</i>	Nanjing Chuangken Magnetism Co. Ltd <sup>1, 2</sup> <i>China</i>
			KJ Magnetics <sup>2</sup> <i>US</i>	Ningbo Ninggang Permanent Magnetic Materials Co. Ltd <sup>1, 2</sup> <i>China</i>
				Advanced Technology & Materials Co., Ltd. <sup>2</sup> <i>China</i>
				Beijing Jingci Magnetism Technology Co. <sup>2</sup> <i>China</i>
				Thinova Co., Ltd. <sup>2</sup> <i>China</i>
				Ningbo Yunsheng Co., Ltd. <sup>2</sup> <i>China</i>
				San Huan New Material High-Tech Inc. <sup>2</sup> <i>China</i>

# Rare Earth Element Materials Suppliers

## Magnets

Samarium cobalt rare earth magnets used by DoD systems are provided by companies including Dexter Magnetics, Arnold Magnetic Technologies, Electron Energy Corporation, Magnet Component Engineering, Integrated Magnetics, Adams Magnetic Products, Vacuumschmelze, Magnet Applications and Thomas Skinner. Some of these companies produce samarium cobalt magnets which comply with section 10 USC 2533b of the U.S. Code, but most procure magnets and finish them to final desired forms and functions . There is currently no U.S.-based manufacturer of sintered Neodymium Iron Boron magnets.

## Metals

There is currently extremely limited U.S. production capability at Santoku and Great Western Technology. Another limited supply is available from the U.K.-based Less Common Metals. The majority of rare earth metals are procured from China.

## Oxides

97% of rare earth oxides are produced in China.

# Select Components Utilizing Rare Earth Materials

## Actuators, Motors and Generators

- Neodymium Iron Boron (NdFeB) & Samarium Cobalt (SmCo) Magnets
- Neodymium-Praseodymium (Nd-Pr) mixture

## Phosphors and Displays

- RE-Doped Yttria Alumina Garnet (YAG) and other phosphors
- Cerium-Oxide (CeO) & Lanthanum-Oxide (LaO) as glass additives

## Structural Materials

- Magnesium alloys, super alloys, ceramics, thermal barrier coatings, iron & steel

## Sensors and Electronics

- Sonar (Terfenol-D), Accelerometers, and Gyroscopes

## Radar

- Yttrium Iron Garnet (YIG) & Yttrium Gadolinium Garnet (YGG) microwave devices
- SmCo magnets used in Traveling Wave Tubes (TWT), magnetrons, and klystrons
- Gadolinium Iron Garnets & Yttrium Lanthanum Fluoride crystals for microwave applications

## Lasers

- Yttria Alumina Garnet (YAG) & Neodymium (Nd) used in target designators and range finders

## Optics and Optical Fiber

- Cerium-Oxide (CeO) concentrate for chemi-mechanical polishing
- Erbium (Er) & Terbium (Tb) in optical fiber amplifiers

## Catalysts

- Lanthanum (La) concentrate in fluid cracking catalysts

# United States Air Force



Predator



JDAM



F-35



JAGM



E-8C



MILSTAR



B-52



GMD Missile

# Miniature Air-Launched Decoy

**Prime Contractor: Raytheon**

**REE Component Suppliers\*:**

- **Fin Actuators**
  - **Supplier: Moog Components Group**



# Joint Air-to-Ground Missile

**Prime Contractor: Raytheon, Boeing**

**REE Component Suppliers\*:**

- **Fin Actuators**
  - **Supplier: Moog Components Group**



Also used by Marine Corps

\*Not Comprehensive



# Exoatmospheric Kill Vehicle

**Prime Contractor: Raytheon**

**REE Component Suppliers\*:**

- **Fin Actuator**
  - **Supplier: Moog Components Group**



# GMD Missiles

**Prime Contractor: Boeing**

**REE Component Suppliers\*:**

- **Fin Actuators**
  - **Supplier: Moog Components Group**



# RQ-4 Global Hawk UAV

**Prime Contractor: Northrop Grumman**

**REE Component Suppliers\***

- Hydraulic Pump Motor
  - Supplier: Electromech Technologies



Also used by Army, Navy

\*Not Comprehensive

# MQ-1 Predator

**Prime Contractor: General Atomics**

**REE Component Suppliers\***

- Multi-Spectral Targeting System
  - Supplier: Raytheon
- Hydraulic Pump Motor
  - Supplier: Advanced Industries



Also used by Army

\*Not Comprehensive

# MQ-9 Reaper

**Prime Contractor: General Atomics**

**REE Component Suppliers\***

- Multi-Spectral Targeting System
  - Supplier: Raytheon



Also used by Army, Navy

\*Not Comprehensive

# AMRAAM

**Prime Contractor: Raytheon**

**REE Component Suppliers\***

- Mid-Fuselage Fins



Also used by Marine Corps

\*Not Comprehensive

# F-15

**Prime Contractor: BOEING  
(McDonnell Douglas)**

**REE Component Suppliers\***

- Engines
  - Supplier: Pratt & Whitney
- Sensors & Communications (AN/ALR-56, AN/APG-63, LANTIRN (F-15E))
  - Suppliers: BAE, Raytheon, Lockheed Martin
- Countermeasures (AN/ALQ-135)
  - Supplier: Northrop Grumman



Also used by Navy

\*Not Comprehensive

# F-16

## Prime Contractor: Lockheed Martin

### REE Component Suppliers\*

- Engines
  - Supplier: Pratt & Whitney
- Sensors & Communications (AN/APG-66, LANTIRN, LITENING, LITENING AT)
  - Suppliers: Northrop Grumman, Lockheed Martin, Rafael
- Countermeasures (AN/ALQ-187)
  - Supplier: Raytheon





# F-22 Raptor

**Prime Contractor: Boeing and Lockheed Martin**

**REE Component Suppliers\***

- Engines
  - Supplier: Pratt & Whitney
- Sensors & Communications (AN/AAR-56, AN/ALR-94, AN/APG-77, ICNI)
  - Supplier: Lockheed Martin, BAE Systems Northrop Grumman, ITT Industries
- Countermeasures (AN/ALE-52)
  - Supplier: BAE Systems



# F-35 Joint Strike Fighter

**Prime Contractor: Lockheed Martin**

REE Component Suppliers\*

- Engines
  - Supplier: Pratt & Whitney
- Sensors & Communications (AN/APG 81)
  - Supplier: Northrop Grumman,
- Generator (Electric Power and Conversion System)
  - Supplier: Hamilton Sundstrand
- Actuator (Flight Actuation Control Electronics Module)
  - Supplier: Hamilton Sundstrand



Also used by Marine Corps , Navy

\*Not Comprehensive

# B-1B Lancer

## Prime Contractor: Boeing

### REE Component Suppliers\*

- Engines
  - Supplier: General Electric
- Sensors & Communications (AN/ALR-56, AN/APQ-164, Sniper XR)
  - Suppliers: BAE, Northrop Grumman, Lockheed Martin
- Countermeasures (AN/ALE-50, AN/ALE-55, AN/ALQ-161A, AN/ALQ-214 IDECM)
  - Suppliers: Raytheon, BAE, EDO Corp, ITT Industries



# B-52

## Prime Contractor: Boeing

### REE Component Suppliers\*

- Engines
  - Supplier: Pratt & Whitney
- Sensors & Communications (AN/ALR-46, AN/ALR-56, LITENING AT, LITENING II)
  - Suppliers: Northrop Grumman, BAE, Rafael
- Countermeasures (AN/ALQ-122, AN/ALQ-155, AN/ALQ-172)
  - Suppliers: Northrop Grumman, ITT Industries



# C-130

## Prime Contractor: Lockheed Martin

### REE Component Suppliers\*

- Engines
  - Supplier: Rolls-Royce
- Sensors & Communications (AN/ALR-46, AN/ALR-69, MWS-20)
  - Suppliers: Northrop Grumman, Raytheon
- Countermeasures (AN/ALQ-156, AN/ALQ-157, AN/ALQ-173)
  - Supplier: BAE Systems



Also used by Army, Marine Corps

\*Not Comprehensive

# E-8C Joint Stars

**Prime Contractor: Northrop Grumman**

**REE Component Suppliers\***

- Engines
  - Supplier: Pratt & Whitney
- Sensors & Communications (AN/APY-3, FBCB2)
  - Supplier: Northrop Grumman



Also used by Marine Corps

\*Not Comprehensive

# AN/ALE 50 Towed Decoy System

**Prime Contractor: Raytheon**

REE Component Suppliers\*

- Travelling Wave Tube (TWT)



Also used by Navy

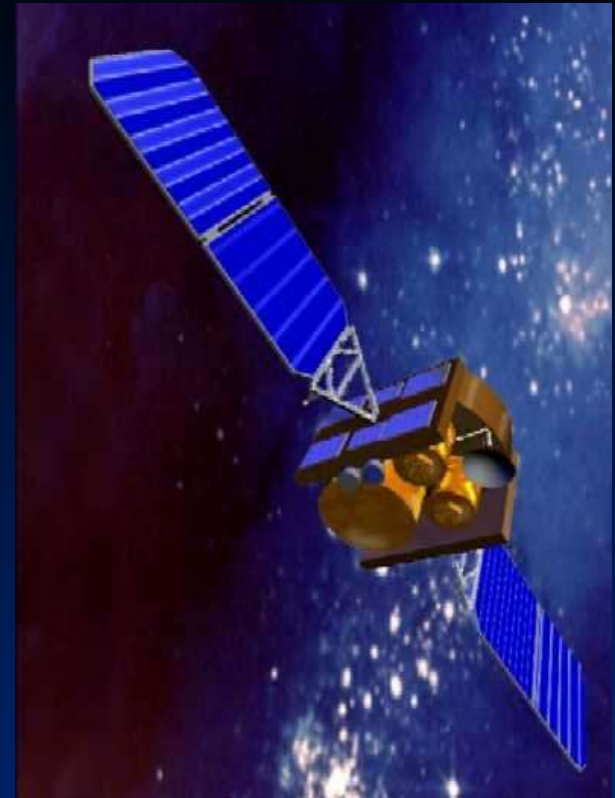
\*Not Comprehensive

# DSCS III

**Prime Contractor: Lockheed Martin**

REE Component Suppliers\*

- Payload (6-channel SHF transponder system)
- Antennas (Wideband multi-beam and two earth coverage receive antennas; two transmit multi-beam, gimbaled dish, and two earth coverage antennas)





# Milstar and Successor Programs

**Prime Contractor: Lockheed Martin**

REE Component Suppliers\*

- Radio frequency (RF), microwave, and antenna subsystems (Milstar II)
  - Supplier: Boeing



# UHF Follow-on (UFO) Satellite

**Prime Contractor: Boeing**

REE Component Suppliers\*

- Payload (4 130-watt, Ka-band transponders)
- Antennas



# Wideband Global SATCOM

**Prime Contractor: Boeing**

REE Component Suppliers\*

- Xenon-ion propulsion system
- Triple-junction gallium arsenide solar cells
- Antennas



# Joint Direct Attack Munition

**Prime Contractor: Boeing**

**REE Component Suppliers\***

- Tail fin actuator motors
  - Supplier: HR Textron
- Electric Motor
  - Supplier: sL Montevideo



Also used by Navy

\*Not Comprehensive

# B-2 Stealth Bomber

**Prime Contractor: Northrop Grumman**

**REE Component Suppliers\***

- Engines
  - Supplier: General Electric
- Sensors & Communications (AN/AAR-54 and AN/APQ-181)
  - Suppliers: Northrop Grumman, Raytheon
- Countermeasures (AN/APR-50)
  - Supplier: Lockheed Martin



# RC-135

## Prime Contractor: Boeing

### REE Component Suppliers\*

- Countermeasures (AN/ALE-47)
  - Supplier: BAE Systems
- Engines
  - Supplier: CFM International
- Sensors & Communications (AN/APN-242)
  - Supplier: Sperry Martin



# KC-135

## **Prime Contractor: Boeing** **REE Component Suppliers\***

- Engines
  - Supplier: CFM International
- Sensors & Communications (AN/APN-242)
  - Supplier: Sperry Martin



# United States Army



Javelin



Blackhawk



C-130



Patriot



HMMWV



AN/TPQ 36



WIN-T



M1A1 Abrams



# Javelin Missile

**Prime Contractor: Lockheed Martin,  
Raytheon**

**REE Component Suppliers\*:**

- **Fin Actuators**
  - **Supplier: Parker-Hannifin**



# Excalibur Artillery Shell

**Prime Contractor: Raytheon**

REE Component Suppliers\*:

- Canard Fin Actuators
  - Supplier: General Dynamics OTS (Versatron)



Also used by Marine Corps

\*Not Comprehensive

# HMMWV

**Prime Contractor: BAE Systems**

REE Component Suppliers\*:

- 45kW Permanent Magnet Generator



Also used by Marine Corps

\*Not Comprehensive

# MH-60R Strikehawk

**Prime Contractor: Lockheed Martin and Sikorsky Aircraft Corp.**

## REE Component Suppliers\*

- Engines
  - Supplier: General Electric
- Sensors & Communications (AN/AAS-52, AN/APS-147, AN/AQS-22 ALFS, AN/ARC-210, ARPDDS, AN/AAS-44(C))
  - Suppliers: Raytheon, Telephonics, Rockwell Collins, Lockheed Martin
- Countermeasures (AN/ALQ-144A, AN/ALQ-210)
  - Suppliers: BAE and Lockheed Martin



# M1A1 Abrams Tank

**Prime Contractor: General Dynamics  
(Land Systems Division)**

**REE Component Suppliers\***

- Engines
  - Supplier: Honeywell
- Sensors (LRS-2000 Rate Sensor)
  - Supplier: Northrop Grumman
- Firepower Enhancement Program
  - Supplier: Raytheon



# AN/TPQ 36

**Prime Contractor: Thales Raytheon Systems (developer); Northrop Grumman (manufacturer)**

**REE Component Suppliers\*:**

- Firefinder Radar



Also used by Marine Corps

\*Not Comprehensive

# MPQ 64

**Prime Contractor: Thales Raytheon Systems**

**REE Component Suppliers\*:**

- Firefinder Radar



Also used by Marine Corps

\*Not Comprehensive

# AN/APS 147

**Prime Contractor: Telephonics Radar Systems**

**REE Component Suppliers\*:**

- IFF Interrogator



Also used by Navy

\*Not Comprehensive



# WIN-T

**Prime Contractor: General Dynamics  
C4 Systems**

REE Component Suppliers\*

- Antenna System



# Patriot

**Prime Contractor: Raytheon**

REE Component Suppliers\*

- Missile: Travelling Wave Tubes (TWT)
- Radar System: TWT
- RF Circulators: Yttrium-Gadolinium Garnets (YGG)



# United States Marine Corps



**Harrier**



**HMMWV**



**AMRAAM**



**JAGM**



**EA-6B Prowler**



**M1A1 Abrams**

# F-18

**Prime Contractor: BOEING (McDonnell Douglas)**

**REE Component Suppliers\***

- Engines
  - Supplier: General Electric
- Sensors & Communications (AN/AAR-50, AN/AAS-38, AN/APG-65, LITENING AT, ALR-67)
  - Supplier: Raytheon, Hughes Aircraft, Lockheed Martin
- Countermeasures (AN/ALQ 126B)
  - Supplier: BAE Systems



Also used by Navy

\*Not Comprehensive

# EA-6B Prowler

**Prime Contractor: Northrop Grumman**

## REE Component Suppliers\*

- Engines
  - Supplier: Pratt & Whitney
- Sensors & Communications (LITENING AT)
  - Suppliers: Northrop Grumman and Rafael
- Countermeasures (AN/ALQ-126B, AN/ALQ-218 TJSR, AN/ALQ-99 TJS (20))
  - Suppliers: BAE Systems, Northrop Grumman, Times Microwave, Selex Sensors, and Airborne Systems



Also used by Navy

\*Not Comprehensive

# Harrier

## Prime Contractor: Boeing

### REE Component Suppliers\*

- Engines
  - Supplier: Rolls-Royce
- Sensors & Communications (AN/AAR-57 CMWS, AN/ALR-67, LITENING, LITENING AT, LITENING ER, LITENING II)
  - Suppliers: BAE, Raytheon, Northrop Grumman, Rafael
- Countermeasures (AN/ALQ-164)
  - Supplier: BAE



# CH-53 Sea Stallion

**Prime Contractor: Sikorsky Aircraft Corp.**

**REE Component Suppliers\*:**

- Engines
  - Supplier: General Electric
- Sensors & Communications (AN/AAR-60, AN/ALR-46)
  - Supplier: EADS, MBDA, Northrop Grumman
- Countermeasures (AN/ALQ-157, AN/ALE-47, AN/AAQ-24)
  - Suppliers: BAE Systems, Northrop Grumman



Also used by Navy

\*Not Comprehensive

# CH-46 Sea Knight

**Prime Contractor: Sikorsky Aircraft Corp.**

**REE Component Suppliers\*:**

- Countermeasures (AN/ALQ-157, AN/ALE-47, AN/AAQ-24)
  - Suppliers: BAE Systems, Northrop Grumman
- Engines
  - Supplier: General Electric





# United States Navy



**E-2 Hawkeye**



**Zumwalt**



**Global Hawk UAV**



**Sea Stallion**



**Phalanx CIWS**



**Trident**

# Phalanx CIWS

**Prime Contractor: Raytheon**

**REE Component Suppliers\***

- Gun azimuth and elevation permanent magnet motors
  - Supplier: Kollmorgen



# Zumwalt Destroyer

**Prime Contractor: Northrop Grumman**

**REE Component Suppliers\*:**

- Permanent Magnet Motor and Drive
  - Supplier: DRS Technologies



# Standard Missile 3

**Prime Contractor: Raytheon**

REE Component Suppliers\*

- Fin Actuators



# Trident Missile

**Prime Contractor: Lockheed Martin**

REE Component Suppliers\*

- Permanent Magnet Motors



# EA-18G Growler

## Prime Contractor: Boeing

### REE Component Suppliers\*

- Engines
  - Supplier: General Electric
- Sensors & Communications (AN/APG-79, JHMCS (2))
  - Suppliers: Raytheon and Boeing
- Countermeasures (AN/ALE-47, AN/ALQ-218 TJSR, AN/ALQ-99 TJS, INCANS, Next Generation Jammer)
  - Suppliers: BAE, Northrop Grumman, Times Microwave, Selex Sensors and Airborne Systems, EDO Corp



# E-2 Hawkeye

**Prime Contractor: Northrop Grumman**

REE Component Suppliers\*

- Engines
  - Supplier: Rolls-Royce
- Sensors & Communications (AN/ALR-73, AN/APS-145, AN/APX-100 (V))
  - Suppliers: Northrop Grumman and Raytheon
- Countermeasures (AN/ALQ-217)
  - Supplier: Lockheed Martin



# MH-60R Seahawk

**Prime Contractor: Lockheed Martin and Sikorsky Aircraft Corp.**

## REE Component Suppliers\*

- Engines
  - Supplier: General Electric
- Sensors & Communications (AN/AAS-52, AN/APS-147, AN/AQS-22 ALFS, AN/ARC-210, ARPDDS, AN/AAS-44(C))
  - Suppliers: Raytheon, Telephonics, Rockwell Collins, Lockheed Martin
- Countermeasures (AN/ALQ-144A, AN/ALQ-210)
  - Suppliers: BAE and Lockheed Martin





# Nulka MK 53 Decoy

**Prime Contractor: BAE Systems Australia**

**REE Component Suppliers\***

- Electronic Warfare Payload
  - Supplier: Lockheed Martin
- Solid Rocket Motor
  - Supplier: Aerojet



# AN/ALE 55 Decoy

**Prime Contractor: BAE Systems**

REE Component Suppliers\*

- Travelling Wave Tubes



# Virginia-class Submarine

**Prime Contractor: General Dynamics Electric Boat  
and Northrop Grumman Newport News**

## REE Component Suppliers\*

- Propulsion
  - Supplier: General Electric
- Sensors & Communications (A-RCI, AN/BPS-16, Sub HDR, TB-29, TB-34)
  - Suppliers: Lockheed Martin, Northrop Grumman, Raytheon
- Generators



# Aegis Radar

Prime Contractor: Lockheed Martin

REE Component Suppliers\*:

- Crossfield Amplifiers



# P-3 Orion

**Prime Contractor: Lockheed Martin**

**REE Component Suppliers\*:**

- Sensors & Communications (AN/ASQ-81)
  - Supplier: Raytheon
- Countermeasures (AN/ALQ-157)
  - Supplier: BAE Systems



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