Creating a Multi-National Platform:
Thorium Energy & Rare Earth Value Chain

Assessing Rare Earths and Global Imbalance
Chinese Industrial Policy vs. Adverse NRC/IAEA Policy = Market Failure
Will Thorium Energy Systems be next?

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Rare earths and Thorium have become linked at the mineralogical and geo-political level.

Regulatory changes pertaining to Thorium contributed to excessive market concentration in rare earths.

This has resulted in economic dislocation and National Security issues for many countries.

A solution is required.
Rare Earths consist of the full Lanthanide Series plus Yttrium and Scandium (Y + Sc)

Pm – Promethium does not exist within the earth’s crust, cannot be mined, has no uses or applications and will be eliminated from this discussion

Below is the full spectrum of commercial Rare Earths

All 16* elements are necessary in the production of modern technologies and advanced weapons systems

* Pm – Promethium does not exist within the earth’s crust, cannot be mined, has no uses or applications and will be eliminated from this discussion
In The Beginning...

From the 1890s to the early 1900s Monazite was mined, not for its rare earth content, but for its companion element Thorium (for gas mantels).

Monazite was the primary source (99%) of rare earths from the early 1900s until about 1964.

Monazites were primarily a byproduct of heavy mineral sands mining operations.
In the early 1980s China could not meet western standards and had to exit the rare earth market. The U.S. and France remained global leaders in rare earth refining and metallurgy. At this time Monazite supplied nearly 100% of the world's heavy rare earths.

Data Produced by USGS: James Hedrick, Gordon Haxel and Greta Orris

From 1956 to 1964 Monazites supplied about 99% of the world's rare earths.

Mt. Pass's sharp growth reflected phosphor demand for color televisions.
The end of commercial Monazite production began in the mid-1980s due to “classification” changes instituted by the NRC and the IAEA, effectively defining Monazites as “Source Material” due to its Thorium content.

Just prior to these classification changes Monazite represented nearly 50% of global rare earth supply and close to 100% of the world’s heavy rare earths.
China’s market advantage evolved from changes in NRC / IAEA resource classification, defining Monazite as “Source Material,” and China’s implementation of an aggressive, top down, industrial policy. This Classification Ultimately Forced others to Exit the Rare Earth Industry. In 2002 the Mt. Pass Mine was shut down because of a Thorium discharge – not China.

*Mt. Pass Decline (1984): With no high value heavy rare earths, high mining & environmental cost and price competition from China, Mt. Pass struggled to compete
U.S. & Australian companies have invested over $6 billion into new rare earth projects -- with little prospects for success

*Is This Free Market Failure, or Something Else?*

To avoid Thorium liabilities U.S. / global financial markets favored rare earth projects with low Thorium content, not high value rare earth distributions
The leading U.S. RE mine only produces ½ of the RE “elements” needed

*Processed in U.S.    Shipped to China

Red indicates DoE “critical” classification

This deposit does not have any recoverable heavy Lanthanides or Scandium, but the ore-body is low in Thorium. Yttrium recovery is limited by it’s natural distribution within the ore-body. The Australian mining company has a similar low value light RE distribution
This U.S. corporation ships all of its high value REs to China for processing, refining and value adding.

WHAT IS NEEDED - The Full Spectrum of Rare Earths

- Light REs
  - La, Ce, Pr, Nd, Eu, Gd

- Heavy REs + Y, Sc
  - Tb, Dy, Ho, Er, Tm, Yb, Lu, Y, Sc

Shipped to China for Processing

- High Value Light REs + Y
  - La, Ce, Pr, Nd, Eu, Gd, Y

What Gets Processed in the U.S.

- Low Value REs
  - La, Ce

Why did this company become a Supplier to China?
Free Market Strategies facing failure?

USA Approach: Balancing short term returns to its early investors vs. the cost of developing a RE value chain for its low-value rare earth ore dictated that this company acquire and supply refineries inside China (cementing its Thorium in place on-site in California)

Australian Approach: Choose to establish its own RE oxide refinery in Malaysia to get around ‘source material’ issues (leaving its Thorium in Malaysia) and to integrate itself into the OEM / end-user market in Japan
Why Can’t They Compete?

Today both companies are facing unsustainable losses & eventual bankruptcy, resulting from:

1. Large scale production of low-value rare earth that greatly undermine market pricing for all light REs
2. The high cost of direct mining (of low value resources) vs. China’s lower mining cost and its heavy reliance on RE byproduct production (~ 70%)
3. Higher capital costs related to small mining ventures attempting to finance non-traditional / non-mining assets such as refining and value chain facilities
4. Leaving the high-value heavy rare earth market, and its enormous profits, to China
Full Spectrum Rare Earth Production & fully integrated Value Chain

Developing low value rare earth deposits with high direct cost is not economically viable.

High value, low-cost, byproduct resources are abundant and available.

Thorium bearing Rare Earth Phosphates could meet 50% or more of global demand if the Thorium issue could be resolved.

There is no need to develop any new RE mining operations – just fix the Thorium Problem.

Fully Integrated Value Chain Capabilities are Paramount: All efforts must focus on developing a fully integrated value chain.
High Value Rare Earths as Byproducts

U.S. mining companies alone currently mine as much as 50% of global Rare Earth demand every year.

Monazite and other Rare Earth Phosphates mineralization's typically contain all 16 of the Rare Earths + Thorium

Unfortunately these Monazites & RE Phosphates cannot be utilized because of the companion element Thorium

These resources are diverted in tailings lakes or are redistributed back into the host ore-body, due to Thorium
Introducing U.S. Congressional Bills H.R. 4883 & S. 2006
The National Rare Earth Cooperative Act (& Thorium Bank)
These Bills would Allow for the Utilization of Monazite and other Thorium bearing Rare Earth Resources Within a Structured Framework

By Creating a Federally Chartered Multi-National Rare Earth Cooperative – Privately Funded, Operated and;
Authorized to accept Monazites and other Thorium bearing rare earth materials

• by allowing such resources, under existing regulations, to be sold and transported to the rare earth cooperative as:
  “unprocessed and unrefined ores”, per 10 CFR 40

• all Actinides are passed to a Federally Chartered Thorium Bank, to ensure safe, long term storage and future use
Multiple mining companies provide Monazite, Apatite & other Th-bearing REs to the co-operative, currently not commercial or are a waste byproduct of some other commodity.

Multiple RE Suppliers – RE is a byproduct

Thorium liability

RE Refinery Co-op / oxides, metals, alloys, etc.

Not Endorsements – Potential Co-op Owners

Japanese Industry, Korean Industry, EU Industry,
N.A.T.O

Thorium Bank holds all Actinide liabilities, but has Congressional authority to develop “Uses & Markets for Thorium, including Energy”

The Th-Bank assures that Thorium is no longer released into the environment

RE end-users own and control the Co-operative and off-take, but share profits with suppliers
U.S. Congressional Bills H.R. 4883 & S. 2006
Also Establish a Multi-National Development Platform for:

- The creation of a Thorium Bank that will take all liability and physically hold and safely store all Thorium and associated Actinide liabilities from the Rare Earth Cooperative.

- The creation of a Thorium Industrial Products Corporation with Congressional authority to develop industrial uses and markets for Thorium (including decay products) that include:
  1. alloys
  2. catalysts
  3. medical isotopes
  4. other uses
also establishes a Multi-National Development Platform for:

The Commercial Development of Thorium Energy Systems, that include:

I. solid fuels from Thorium
II. solid-fuel reactor technology
III. beam / accelerator driven reactor technology
IV. liquid-fuel reactor technology, to include
   i. electric power
   ii. thermal energy
   iii. synthetic liquid fuel production
   iv. desalination
   v. nuclear waste reduction (actinide burners)
   vi. hardened and deployable energy systems
A multi-national corporation to develop uses and markets for Thorium, including energy systems.
Why is this new Multi-National Platform important? Consider This:

‘no technologically important & wide spread industry ever began in a regulated environment...’

and the current environment demands conformity to the standard paradigm

This legislation would create an unrestrained R&D Platform for all IAEA member states to share and participate in the commercial development of true Next-Generation technology
Evolution or Revolution?

Germany, Japan and politically active groups across the globe want an alternative to LWR / BWR and other solid fueled / water cooled reactors

-- they demand something new

Embrace it or oppose it, an alternative is just around the corner. Inaction will create just a single winner. Collaborative action assures that we all win.

This structure allows all IAEA member states to build that future together and share the rewards.
International Atomic Energy Agency
URAM - Symposium on Uranium and Raw Materials for the Nuclear Fuel Cycle: Exploration, Mining, Production, Supply and Demand, Economics & Environmental Issues
IAEA Headquarters, Vienna Austria, June 23 – 27, 2014
A significant part of our Nation’s defense systems are heavy RE dependent.

### Heavy RE Dependent Technologies

- **Tb**
  - Magnets, Lighting & Phosphors, Fuel Cells – Automotive, Wind Turbines
  - Defense Applications: Terfenol-D Sonar, Guided Ordinance, Lasers
- **Dy**
  - Magnets, Nuclear Control Rods, Lasers – Automotive, Wind Turbines
  - Defense Applications: Terfenol-D Sonar, Guided Ordinance
- **Ho**
  - Magnets, Nuclear Control Rods, Lasers, Microwave Equipment
  - Defense Applications: Rail Gun, Direct Energy Weapons, EMPs, Electro-Lasers
- **Er**
  - Industrial & Medical Lasers, Fiber Optics, Nuclear Control Rods, EU Currency
  - Defense Applications: Infra-Red CM, LADAR, Communications
- **Tm**
  - Super Conductors, X-Ray, Industrial & Medical Lasers, Optic Display, EU Currency
  - Defense Applications: Magnets, CTH YAG Lasers
- **Yb**
  - X-Ray, Optics, Steel Alloy, Stress Instrumentation, Solar Cells, Lasers
  - Defense Applications: Advance Photonics Phase-Lock Array Lasers
- **Lu**
  - Nuclear Dating, Metal Alloys, Catalysts, Medical Imaging and Treatments
  - Defense Applications: Active / Passive Infra Red Cameras, Scintillators
- **Sc**
  - Supper Aluminum Alloys, Specialty Lighting, Lasers, Fuel Cells
  - Defense Applications: Air Frame Alloys and Missile Hardening
- **Y**
  - Phosphors, Electrodes, Super Conductors, Lasers, Catalysts
  - Defense Applications: Guided Ordinance, Lasers, Communication, Radar

None of these are currently produced in the USA.

Under the current ‘free market’ approach (Molycorp’s Mt. Pass) the problem is grossly exacerbated because Molycorp sends all of its valuable light REs to China also.
<table>
<thead>
<tr>
<th></th>
<th>Mt. Pass Bastnaesite</th>
<th>China Byan Obo</th>
<th>HRE-China Laterite</th>
<th>Selected Monazite</th>
<th>Pea Ridge* Breccia</th>
<th>Pea Ridge** RE-Apatite</th>
<th>Florida Phosphate</th>
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<td>Trace</td>
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<td>Trace</td>
<td>Trace</td>
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<tr>
<td><strong>Percent Heavy</strong></td>
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<td>0.3%</td>
<td>18.1%</td>
<td>4.7%</td>
<td>4%</td>
<td>7.5%</td>
<td>10%</td>
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<tr>
<td><strong>Heavy + Y</strong></td>
<td>0.1%</td>
<td>0.5%</td>
<td>83.1%</td>
<td>8%</td>
<td>9.7%</td>
<td>25%</td>
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<tr>
<td><strong>RE in Ore</strong></td>
<td>8%</td>
<td>5%</td>
<td>0.2%</td>
<td>+50%</td>
<td>12%</td>
<td>3%</td>
<td>3%</td>
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<tr>
<td><strong>Percent Th</strong></td>
<td>0.1%</td>
<td>0.3%</td>
<td>&gt;.1%</td>
<td>8%</td>
<td>3.5%</td>
<td>1%</td>
<td>10.5%***</td>
</tr>
</tbody>
</table>

USGS Data - In order of Geologic Occurrence – Bastnaesite, HRE Laterite, Monazite, Apatite

*Pea Ridge RE resources: Breccia Pipes (primarily Monazite / limited Xenotime).
**Rare Earth Enriched Apatite (Monazite / Xenotime), a no-cost byproduct of iron ore mining.
***Total Actinides = Thorium and Uranium (USGS data), but totals 2 times U.S. annual rare earth demand.

Just one non-rare earth mine in the U.S. dumps over 100% of U.S. annual consumption demand every single year. Historically this same mine was the exclusive domestic producer of all U.S. heavy rare earths.
China retains 99.9% control of heavy REs

Light Rare Earths ~ 80% La + Ce

La + Ce = 80%