

**World Congress on  
Materials Research & Technology**

**Theme: Recent Trends in Materials  
Science and Technology**



# **Global Trends In Rare Earth Patents And Other Macro Trends**

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# Rare Earths in Material Science & Technology

The 16 naturally occurring rare earth elements play an increasingly important role in all areas of material science and technology

21	39	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
<b>Sc</b>	<b>Y</b>	<b>La</b>	<b>Ce</b>	<b>Pr</b>	<b>Nd</b>	<b>Pm</b>	<b>Sm</b>	<b>Eu</b>	<b>Gd</b>	<b>Tb</b>	<b>Dy</b>	<b>Ho</b>	<b>Er</b>	<b>Tm</b>	<b>Yb</b>	<b>Lu</b>
Scandium	Yttrium	Lanthanum	Cerium	Praseodymium	Neodymium	Promethium	Samarium	Europium	Gadolinium	Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium	Lutetium
44.956	88.906	138.906	140.115	140.908	144.24	144.913	150.36	151.966	157.25	158.925	162.50	164.930	167.26	168.934	173.04	174.967

Rare earths are a critical component in:

**All**

Computers  
Smart Phones  
Nuclear Reactors  
Petroleum Refining  
Medical Imaging  
High Power Lasers

**Most**

Green Technologies  
Advanced Weapons  
Modern Combustion,  
Hybrid & Electric Autos  
Advanced Optics, Ceramics,  
Metallurgy & Electronics

**Pm:** *Promethium is not a naturally occurring element in the earth's crust*

# Economic Scope of Rare Earths

Rare earth dependent technologies and processes equate to about \$ 7 trillion dollars in annual revenues, or about 10 percent of the global economy

10 percent does not sound like much, but this 10 percent of the global economy sits at the center of the bell curve where all of the profits are made.

This 10 percent of the economy is also the portion that demands and funds material science research to stay competitive.

# R&D Drives Comparative Economic Growth

Research & Development (R&D) is the primary driver of new technologies and is a reasonable proxy for the relative competitiveness of technology leaders across industries and rising living standards between advanced economies

- Historical economic growth across economies is most directly correlated to public and private investment into the sciences and new technology
- R&D typically begins with the application of knowledge and/or processes derived from basic, applied and material sciences

# Continued...

Failing to remain on the leading edge of R&D undermines the economic competitiveness of manufacturing & technology companies and nations

- Because industrial leadership tends to follow scientific leadership, measured across individual product lines, technology sectors or entire industries
- And become self-advancing via positively correlated funding feedback loops within corporations, industries and economies through public and private funding of the sciences and R&D

Consequently, if a nation becomes a research or efficiency leader in one or more technology sectors, other businesses tend to grow in or migrate to that nation (to maintain or advance competitiveness)

# Relative Leadership in the Basic Sciences & R&D

Leadership can be defined on aggregate measures or via specialization

Historically larger leading economies tended to take a shotgun approach to the sciences

Smaller economies remained competitive with larger economies through directed focus on applied research that complimented their leading industries

- An industrial 'break-out' for any of these smaller economies typically results in increases of economic growth and R&D funding

Although not perfect, these national strategies allowed for economic parity and economic stability

# Today That Paradigm Is Shattered

The relative R&D investment rates across differing national economic models has resulted in unassailable disparities between national economies – measured individually or collectively

- Today most leading economies increasingly rely on private sector investment into R&D, with greatly reduced funding on basic, applied and material science

China has broken from this model with spectacular results

- Largely reflecting the U.S.'s pre & post war years of large scale direct government funding for basic and applied sciences (circa 1940 – 1970)

# Continued...

The Chinese model is much more aggressive than the historical U.S. program of pre & post WW2

The Chinese model seeks national-scale advantages in all areas of basic science, applied science, material science, economic trade, advanced manufacturing & critical industries (“Made In China 2025” initiative)\*

Specific to rare earths, China has established an absolute advantage at the resource level and at the commercial production level for advanced materials

This advantage is compounded through the application of preferential taxes & tariffs on trade

\* I am not criticizing China’s methods or motivations, as their actions conform to their national goals and interests. On the contrary, I am critical of ‘our’ individual and collective failure to respond to this reality: pregnant with historical implications & consequence

## Continued...

When collectively coordinated as part of a national economic policy these advantages have resulted in the leveraged relocation of technology, IP and entire industries into China

The rapid concentration of rare earth dependent industries accelerated China's leadership in all areas of related basic science, materials science, applied science, IP, manufacturing and commerce

The use of rare earths as a means of technology transfer is largely misunderstood; with most critics focused on this issue at the resource level

# Putting Things In Perspective

Competing governments have failed to assess or understand the scale of China's rare earth dominance at all levels of science, R&D and the value chain, such as China's:

- Two “Rare Earth Cities” entirely focused on materials production, R&D and commercial applications of rare earth materials, with a combined population of 17 million people
  - Equivalent to 100 times the U.S. WW2 Manhattan Project
- Over 100,000 registered PhDs, researchers and scientists in just one of its rare earth societies

# Continued...

- Four National Laboratories dedicated to basic science, chemistry, materials science, applied science and the metallurgy of rare earths
- The Baotou Research Institute of Rare Earths, the largest rare earth research institute in the world since 1985
- Production of over 80% of the world's rare earth resources\* and value added materials\*\* and internal consumption of as much of its value added materials (metals, alloys, magnets, phosphors, garnets, etc.)

*\*Internal estimates of 'black market' production are 150 percent greater than official production figures*

*\*\*Most non-Chinese rare earth resources pass through China's value chain*

# ***Reality Based Assessment of the RE 'Market'***

## **China is the market**

- Producing & Consuming the majority of global rare earth production

## **Controls production**

- At the mined resources, oxide, metal, alloy magnet, garnet, phosphor, component and finished product level

## **And, thus, is free to set prices at all levels**

- Under a coordinated National Industrial & Defense policy

**Thus, no traditional 'market' based solution can prevail without China's acquiescence...**

*NOTE: China's official and published resource and value chain "capacity" has ranged between 200 and 300 percent of global demand for over a decade*

Continued...

Consequently most, if not all, resource producers who challenge China's monopoly will only help yield more market control to China

- For example, most of the high value RE oxide production of the Lynas rare earth facility passes through China for further refinement or conversion into metals, alloys or magnets
- This was also true for Molycorp

Making them nothing more than low value resource suppliers to China's high value / high tech economy

# Traditional Challenges Have & Will Fail Because

Directly mining rare earth outside of China is pointless:

- Concentrates and oxides have no high value use
- Nearly all rare earth concentrates and oxides in the world pass through China's value chain before they can be incorporated into a higher value application
- China ultimately controls production and pricing of rare earth concentrates, oxides, metals, alloys, magnets, garnets (etc.), components, applications & dependent products

In Short, China ultimately controls the economic viability of any non-Chinese rare earth mine, value chain, dependent product or industry

# Comparative National Investment To Reduce Chinese Disparities & Dependence

- Japan invested nearly \$1.5 billion, with a net 3 percent reduction in dependence for value added materials
- The European Union has budgeted over \$1 billion, with much of its focus on recycling
- Russia has invested over \$1 billion
- The U.S. has invested less than \$50 million, with most of it focused on extracting rare earths from coal\*

*\*And wasting \$130 million looking for 'alternatives' – effectively redirecting its only national lab to abandon rare earth research*

# Continued...

While most of these National commitments appear to be sincere, consider this:

- Deng Xiaoping's family acquired & relocated a \$70 million U.S. rare earth asset\* in the mid 1990s
- Xi Jinping's family invested nearly \$400 million in Chinese rare earth companies by 2012
- China's state sponsored rare earth programs have enjoyed the direct support of the last four paramount leaders\*\*

*\*Magnequench, a former U.S. company and 85 percent patent holder of the NdFeB magnet*

*\*\*Deng Xiaoping and Jiang Zemin instigated Programs 863 and 973 respectively and Xi Jinping and Wen Jiabao maintained foreign investment, export, tariff and trade restrictions on rare earth while continuing internal subsidies and investment into the industry*

So how bad is it ?

# **China's Commitment to Science & Technology vs. All Other Countries Measured in International Patent Filings**

The following graphics were derived from an extensive international patent search by Country of Origin

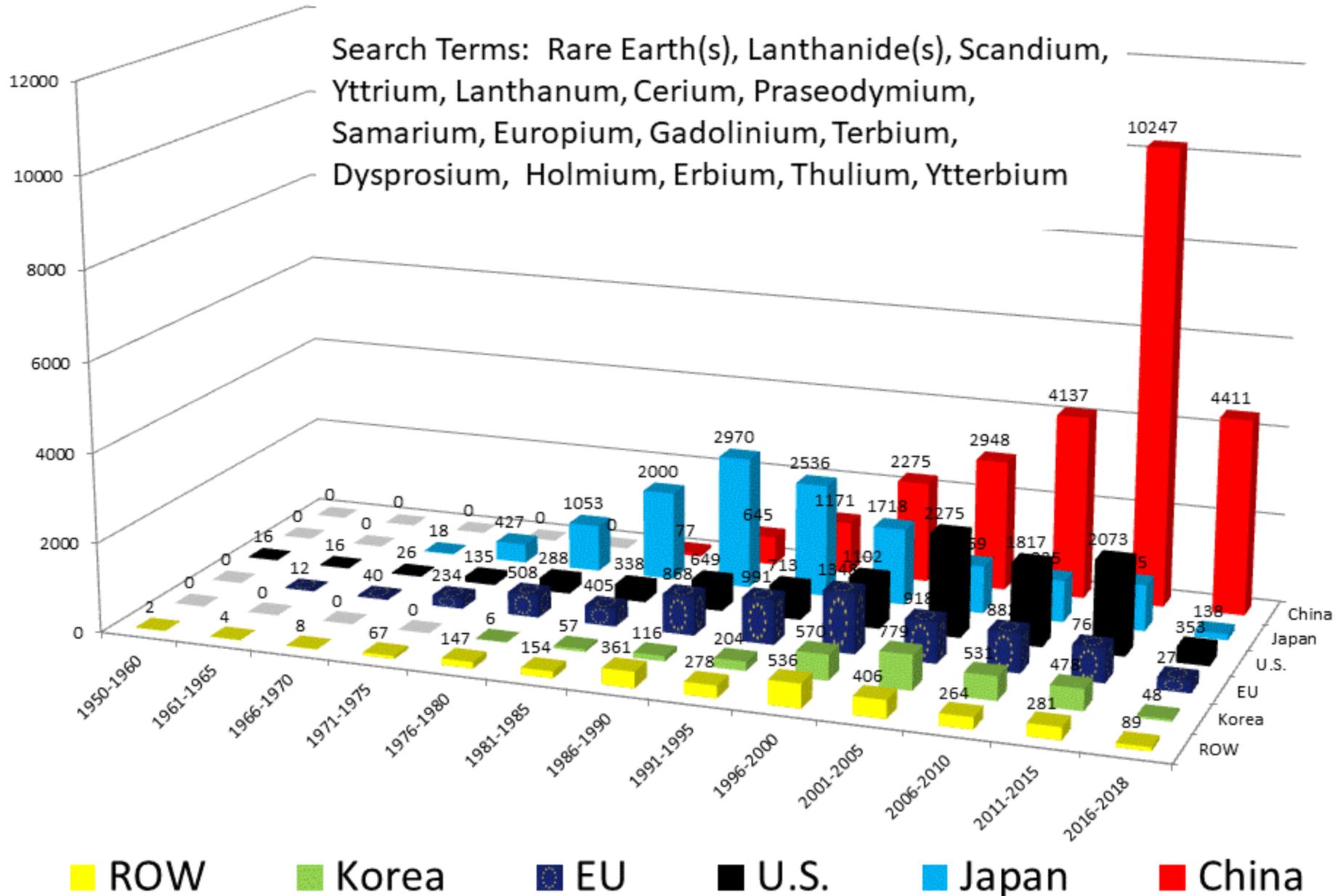
The primary search terms were: **rare earth(s), lanthanide(s), lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, scandium and yttrium**

The search dates were unbounded (from the first filed patent to the last filings of August 2018)

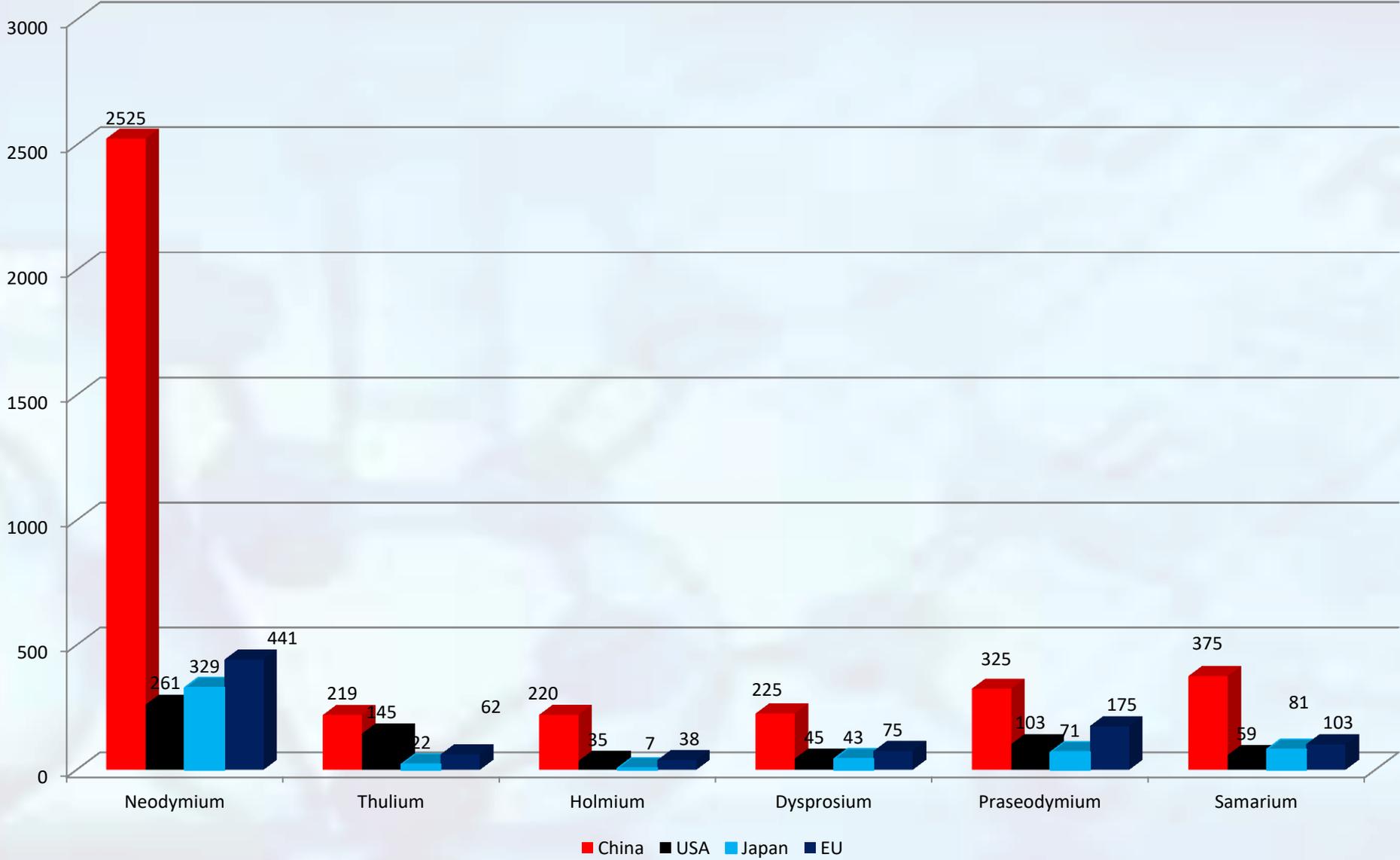
The data set includes over 80,000 patents

# International Patent Filings By Country Of Origin

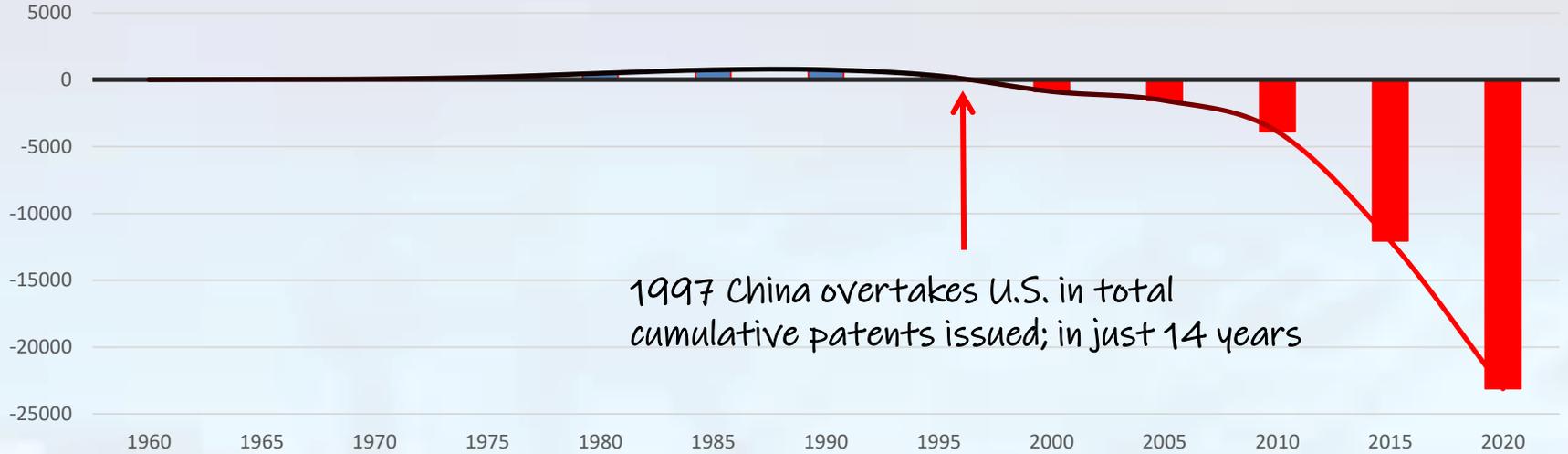
Search Terms: Rare Earth(s), Lanthanide(s), Scandium, Yttrium, Lanthanum, Cerium, Praseodymium, Samarium, Europium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium, Ytterbium



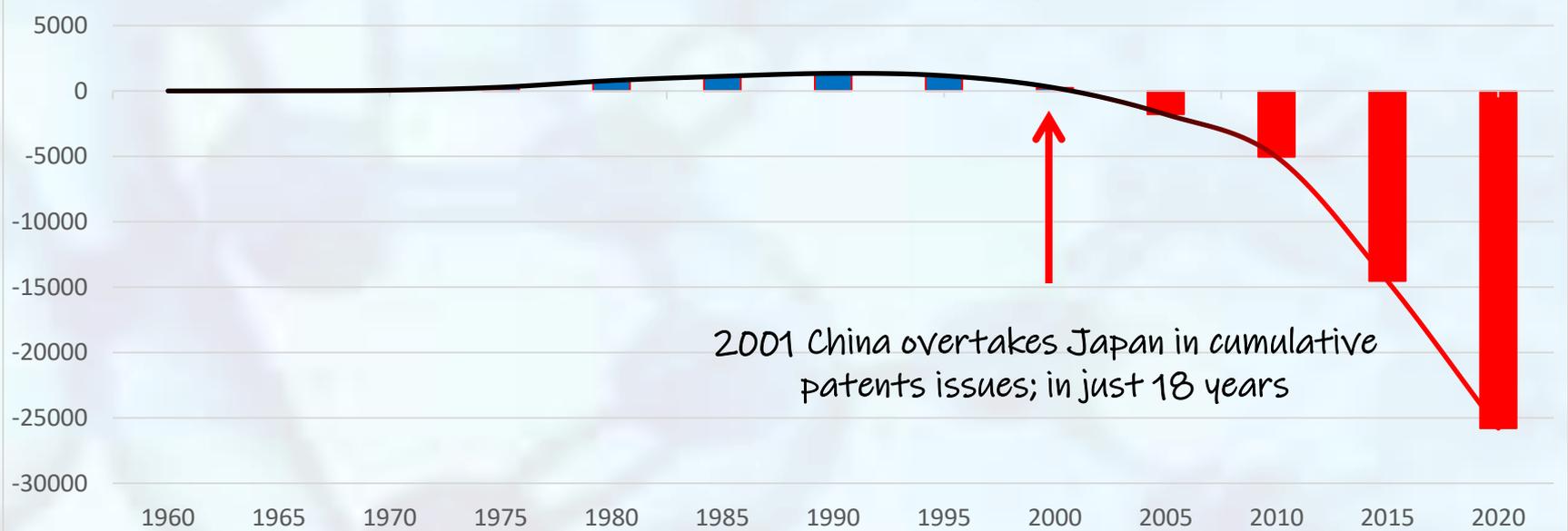
# Cumulative International Rare Earth Patents By Selected Element & Country



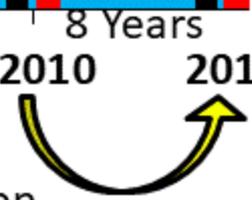
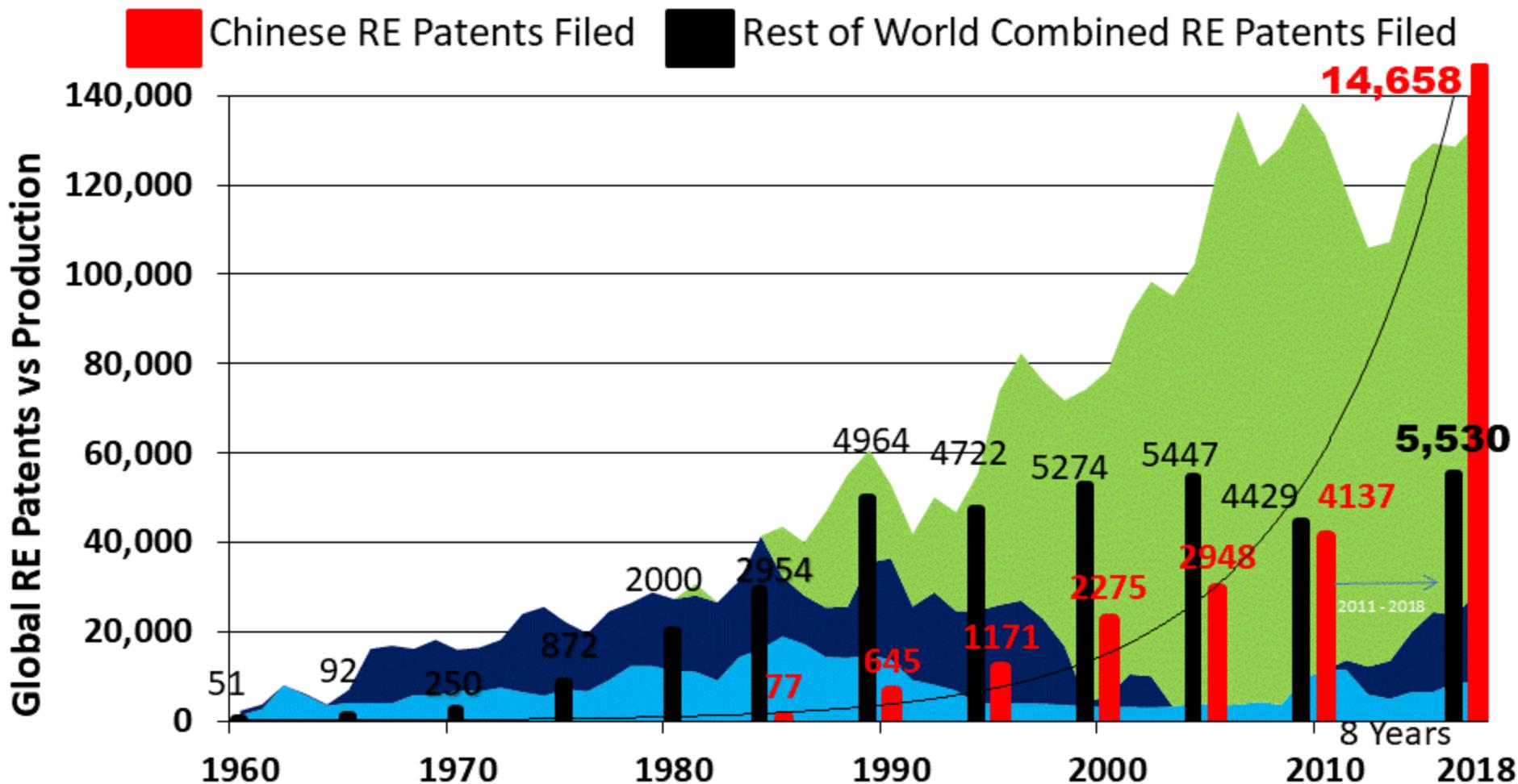
## Cumulative Patent Deficits | US vs. China



## Cumulative Patent Deficits | Japan vs. China



# International Rare Earth Patents vs Rare Earth Production Type



**Official Chinese estimates put "black market" RE production at 150 percent of official numbers**

# Projecting Forward:

China issues more rare earth patent filings each year than the rest of the world combined

Sometime before 2021 China will hold more rare earth patents than the rest of the world combined

- Even more impressive considering their first patent filing was in the early 1980s

China has more dedicated rare earth research professionals and institutions than the rest of the world combined

China's growth in all related areas is accelerating relative to all other nations

# The Walkaway

It should be obvious that no individual corporation, industry or country can remain competitive in materials research against China

Lagging research, compounded through unequal commercial access to rare earth materials and the resulting relocation of rare earth dependent technology, IP and manufacturing to China exacerbates these asymmetric economic disparities

Over time these divergences constitute a powerful reinforcing feed-back loop – as suggested in the data

# Possible Solution

The only non-war-time free market solution is the formation of a multi-national cooperative to balance China's nationally funded commitment

Such a solution is under consideration with the current U.S. Administration, as an Executive Order

The Executive Order would establish an uninterruptable supply chain of resource suppliers\* who would feed concentrates and oxides into a private multi-national rare earth cooperative value chain

\*By utilizing the historical supply of thorium bearing heavy rare earth byproducts currently disposed of by the U.S. mining industry to avoid 1980 NRC / IAEA regulatory changes that terminated these resources from the supply chain

## Continued...

The cooperative would be funded, managed and owned by multi-national rare earth dependent technology companies, rare earth end-user buying groups and participating governments

The cooperative would produce metals, alloys, magnets, garnets, phosphors and other value added materials.

These materials would be sold to the cooperative's owners "at cost"

Any surplus would be sold at 'market prices' and profits would be distributed to the cooperative owners

# Multi-National Cooperative Advantages

Multi-National participation across multiple industries and nations reduces the individual capital commitment for all participants and allows the cooperative to compete 'on-scale' with China

Ownership in the cooperative eliminates U.S. Anti-Trust issues between owner / members

The identity of some members in the cooperative can be protected under U.S. FISA law (the U.S. Foreign Investment National Security law)

# Closing Statement:

It is far past time to act

- At this point in our collective economic history we face the choice of standing together or falling individually

I invite all participants at this conference to initiate an open dialogue between your colleagues, your respective disciplines, your industry partners and your governments to decide how you want this to play out...

- Continued inaction assures an unambiguous future or we can stand together and hold our place in the world

The decision is ours

Thank you for your attention

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314.494.1638



Co

Ru

45  
Rh

Pd

46  
Pd

47  
Rh

48  
Pt

49  
Ir

50  
Pt

80  
Hg

81  
Tl

82  
Pb

# Data Collection: Terms, Duration, Methods & Sources

SEARCH STRATEGY USED IN PERFORMING THE SEARCH: *Search Strategy: The search scope is to perform Global Patent Search on a series of Rare-earth metals including: "rare earths"/ "rare earth", "lanthanides"/ "lanthanide", "Lanthanum", "Cerium", "Praseodymium", "Neodymium", "Samarium", "Erbium", "Gadolinium", "Terbium", "Dysprosium", "Holmium", "Erbium", "Thulium", "Ytterbium", "Lutetium", "Scandium", "Yttrium".*

Time Limits: *There is NO time duration involved. The search is conducted without any time constraints.*

*Search Strategy: The search is performed on patents / published applications disclosing the keyword(s) of "Section-A" in their title. Specifically, the selection criteria of the search is based on these keywords being present in the title of the patents / published patent application.*

*The search is conducting at a global level, with special attention to U.S., Asia and Europe, along with other countries including Australia, New Zealand and African countries.*

*The search is also performed on translated keywords for respective Non-English countries (including China / Korea / Japan etc.) along with different European countries to avoid any loss of results.*

*The search is performed on Keywords / Patent Classes (IPC / CPC/ US) and broad classification to avoid any loss of results.*

*The search is performed on different Global patent databases, inclusive of Domestic patent search databases of various patent office(s) around the World to avoid any loss of results.*

*The search is performed on specific Assignees / Companies and /or inventors to avoid any loss of results.*

*The search is performed by experts in this area to avoid any loss of results or quality of search*

Patent Search Database Coverage: *All known databases, world-wide*