History of Chinese Industrial Advances in Rare Earths & Relative Technological Position to U.S. & RoW[i]

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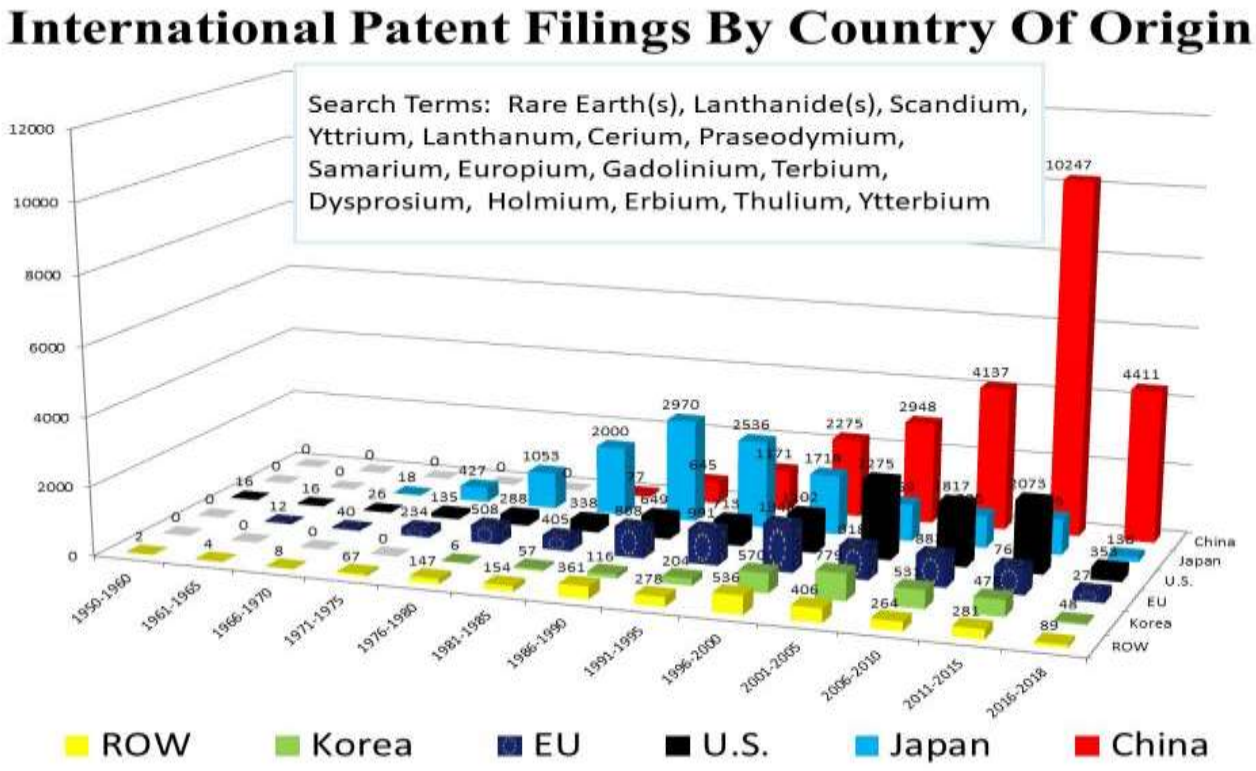
The chart below shows every international rare earth patent that has been filed since 1950, sorted by country of origin.

Patent filings are a reasonable proxy of R&D spending and can foreshadow incremental and next generation advancements in defense and commercial goods. China now leads the world in quantum computing[ii], hypersonic systems[iii], next generation nuclear energy (with defense applications)[iv] and next generation weapons[v] like the rail gun[vi].

The trends expressed in rare earth patents strongly suggest that the Pentagon's 3rd Offset Strategy is stillborn[vii]. National Security is further compromised because the U.S. defense industry remains 100 percent dependent on China for all metallurgical and post-oxide rare earth materials, directly or indirectly[viii].

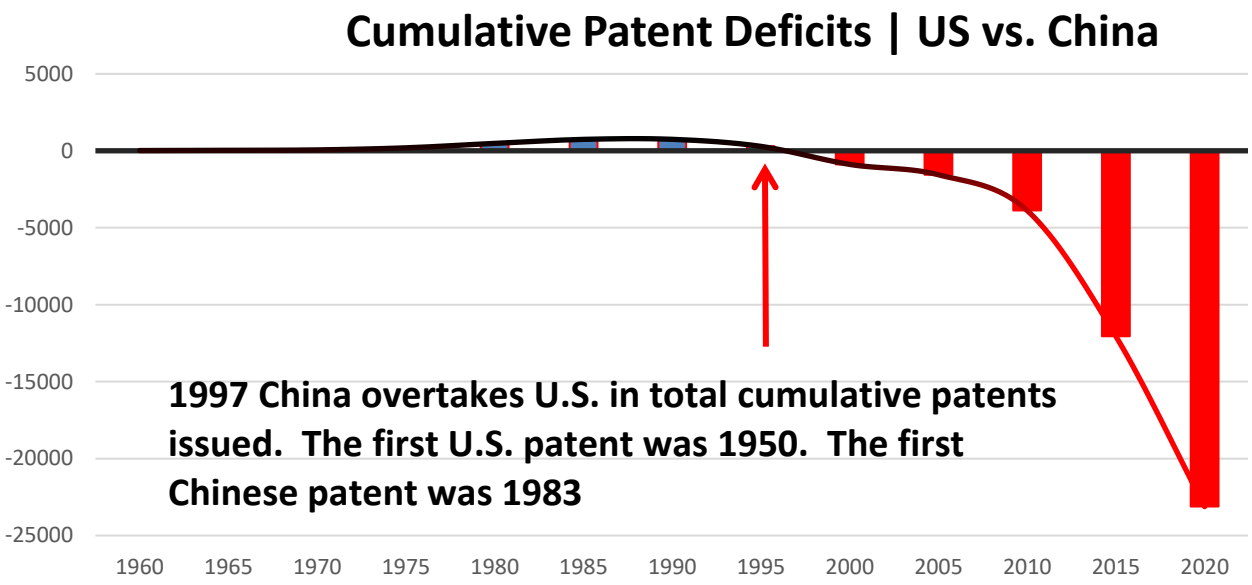


The data set includes every international rare earth patent ever filed, beginning in 1950 through August 2018, with over 80,000 individual patent filings: sorted by country of origin. Search terms listed above.

Summary of Patent Data:

China issues more rare earth patent every year than the rest of the world combined.

By sometime in 2021 China will have accumulated more patents that the rest of the world combined.



China has accumulated a 23,000 patent lead over the U.S. in just 14 years. The trend line does not bode well for the U.S. or the RoW.

China's advances were mostly the result of misguided U.S. policy and the shortsighted transfer of commercial technology (largely promoted under U.S. policy).

I have outlined a partial history of the key historical events and policy failures that made China's ascent possible.

Economic and Strategic Considerations:

China may prove to be the world's largest Patent Troll, using predatory patent tactics to nullify non-Chinese patents. This is done by 'ring-fencing' existing patents with similar patents that differ from the target patent in some 'legally incremental' degree. Recent actions on the part of Chinese companies suggest that this strategy is already in play.

History of Chinese Advances, Mostly As A Result of U.S. Business or Policy Failures

1949	China: The Peoples Republic of China is established
1950	China: Baotou Iron & Steel Company begins production
1950	U.S.: The U.S. files the first international rare earth patent
1951	U.S. – China: Xu Guangxian, regarded as China's father of the rare earth industry, receives his Ph.D. degree with honor from the Department of Chemistry, Colombia University, USA
1952	China: China establishes the General Institute for Non-Ferrous Metals
1952	U.S.: Molybdenum Corporation of America acquired the Mt. Pass mining claims and began mining rare earths in 1952. In 1974 it changed its name to Molycorp. The geo-chemistry of the deposit's primary mineralization is limited to light rare earths and trace amounts of Yttrium, with Cerium and Lanthanum making up over 80% of its rare earth distribution. The company never produced a commercial gram of heavy rare earths and was never a supplier of technology metals. Its primary business evolved into the sale of Lanthanum oxides to the petroleum business, as a cracking catalyst
1957	China: Rare earth concentrate Production begins at Bayan Obo
1963	China: China establishes Bayan Obo Research Institute in Mongolia
1960 - 80	China: National Mineral Exploration & Survey work on rare earths gets the attention of party leadership
1960s	USA: First Rare Earth magnets using Samariaum and Cobalt were developed in the early 1960s based on work done by Karl Strnat and Alden Ray at Wright-Patterson Air Force Base and the University of Dayton – These super powerful magnets were too expensive for commercial application
1966	USA: Nuclear Corporation of America (Nucor) forms Research Chemicals, one of the first commercial metallurgical facilities in the world. Research Chemicals is acquired first by Rhone-Poulenc (1988) and then is sold to Rhodia Rare Earths (1998) and then acquired by Santoku America (1999). Santoku is acquired by Molycorp (2011). Molycorp goes bankrupt in 2015 and Santoku is acquired by Eutectix (2016)
1972	China: Xu Guangxian begins his focus on rare earths and develops Counter Current extraction process.
1978	U.S. – RoW: Instability in Zaire, now known as the Democratic Republic of Congo, results in a 550% price spike in Cobalt, a strategic element used to make the high temperatures Samarium-Cobalt magnets used in military jet engines, microwave communications, and missile fin actuators (then and now the majority of the world's Cobalt comes from the DRC). The Pentagon begins promoting research for alternatives, including grants that helped develop what became the Magnequench NdFeB technology and process.

1978 U.S. – China: Deng Xi Ping requests and is granted a program of scientific transfers through the one-way exchange of Chinese science students to American universities and institutions[ix].

1978 U.S. – China: A U.S. Presidential Directive establishes programs for the transfer of U.S. scientific, technologies related to energy, education, agriculture, geoscience, commerce, public health and space[ii].

1979 U.S. – China: China is granted Most Favored Nation status.

1979 U.S. – China: The United States initiates and funds hundreds of joint research projects and cooperative education programs under the Agreement on Cooperation in Science and Technology[x]

1980 China: China establishes the Chinese Society of Rare Earths

1980 USA: U.S. NRC & IAEA alter "source material" regulations eventually resulting in the termination of heavy rare earth production outside of China. These resources were the byproduct of some other commodity and are now diverted to waste deposits to avoid regulatory costs and liabilities. This action greatly contributed to China's eventual control over the entire rare earth industry

1980 USA: The U.S. Subcommittee on Mines and Mining publishes a warning on U.S. materials and resource dependence. At that time the U.S. was 100% import dependent on just 4 mineral commodities (today 100% import dependence stands at 28, or one-third of the naturally occurring elements on the Periodic Table, with China controlling our access to half of them directly or indirectly)

1980s U.S – China: Beginning in the early 1980s Molycorp begins transferring rare earth beneficiation and processing technology to China[xi].

1981 U.S. – China: The U.S. begins selling advanced air and ground missile technology to China[ii].

1982 U.S. – China: U.S. initiates cooperation on nuclear energy and weapons technology [ii].

1982 USA + Japan: The Neodymium Iron Boron (NdFeB) magnet was simultaneously developed by John Croat with General Motors and Masato Sagawa of Sumimoto Special Metals in Osaka, Japan. The NdFeB magnet is the strongest permanent magnet used in commercial and industrial applications and widely used in defense applications.

1983 China: China begins publication of Chinese Society of Rare Earths Journal (published in Chinese and English abstracts, then full documents and online)

1983 China: China's first international rare earth patent application is filed.

1984 U.S. – China: Expansion of the U.S. funded National Center for Industrial Science and Technology Management Development, in Dalian University of China, to train future managers of Chinese state-owned companies in Western

management practices under the 1979 agreement on Cooperation in Science and Technology[xii] .

1985 China: The Chinese Ministry of Finance, Customs & Taxation began offering tax rebates to Chinese companies and joint-ventures for rare earth exports. This enhanced investment growth in all areas of rare earth production and exports[xiii].

1985 China: Chinese Society of Rare Earths reports that over 3,000 scientists and engineers at over 300 research institutes and 40 universities are working on rare earths in China[xiv]

1985 China - RoW: Baotou Research Institute of Metallurgy is renamed as the Baotou Research Institute of Rare Earths in recognition of the PRC's focus on Rare Earths[xv]. At this time this facility is the largest research organization in the world dedicated to rare earths [vi].

1985 U.S. – China: The U.S. sells over $1 billion in weapon systems to China[ii].

1986 U.S. – China: The U.S. provides funding and assistance to a number of Chinese government research centers focused on lasers, genetic engineering, automation, biotechnology, space technology, intelligent robotics, artificial intelligence, supercomputers [ii].

1986 China: China establishes the national China Rare Earth Information Center

1986 China: China launches Program 863 for the advancement of technology and material sciences, including rare earths under Deng Xiaoping[xvi]

1986 USA: General Motors forms Magnequench. This company was the exclusive domestic producer of NdB magnets for U.S. cruise missiles (Sumitomo corporation held a 15% right over patented production: this was quickly outstripped by internal consumption). These magnets were eventually integrated into other guided missile systems, smart bombs, drones and advanced jet fighters like the F-35

1987 China: China establishes the Changhchun Institute of Applied Chemistry, China's 1st National Lab[xvii] for rare earths – focused on the chemistry and physics of rare earths

1978 -89 China: Ministry of Resources and Planning expands its rare earth focus and operations

1988 China: Since 1983, just 5 years, China's internal rare earth usage has doubled and production has quadrupled[xviii]

1988 Japan – China: Chinese State Planning Commission signs deal with the Japanese Agency for Natural Resources to supply Japan rare earth resources and for Japan to transfer rare earth machinery & process technology to China [viii]

1988 U.S. – China: Tredas International, a U.S. company partners with Chinese Ke Ning Da Industry to produce rare earth magnets[xix]

1990 China: China begins Publication of the Journal of Rare Earths (published in Chinese and eventually in English)

1990 U.S.: Unocal puts the Molycorp Mt. Pass mine up for sale

1991 China: China establishes its 2nd National Lab for rare earth materials: the State Key Laboratory of rare earth materials, focused on chemistry and applications[xx]

1991 China v RoW: The Chinese State Planning Commission formally places the entire rare earth industry under state control and prohibits foreign access or involvement in research, mining, exports, extraction or refining processes. Instead, foreign investment is encouraged to participate in "projects using rare earths"[xxi].

1992 China: Deng Xiaoping establishes rare earths as a central to China's industrial policy, stating: "The Middle-East has oil, China has rare earths"

1992 China: China establishes the Baotou Industrial Development Zone to attract foreign western corporations "for the purpose of technology transfer"

1994 USA: 1993 National Defense Authorization Act authorizes the sale and disposal of all rare earth stockpiles held in strategic reserves in the National Defense Stockpile[xxii]

1994 U.S.: The last U.S. producer of rare earths from monazite, RGC Minerals Inc., ceases production due to increased thorium disposal costs related to the 1980 NRC / IAEA regulatory change[xxiii].

1995 China v ROW: Chinese rare earth production exceeds the rest of the world combined.

1995 China: China establishes the National Non-Ferrous Import Corp, focused on the import and export of rare earths and other technology metals and materials

1995 U.S. – China: Following two years of negotiations General Motors agrees to sell its Magnequench division, the most important rare earth magnet company in the world, to San Huang Group and Sextant MQI holdings. These two entities act as straw-men & shell companies to direct ownership to Deng Xiaoping's family

1996 U.S.: U.S. closes Bureau of Mines – ending the long standing history of our government's involvement in mining & minerals research

1996 U.S.: All U.S. DoE rare earth materials are transferred into the National Defense Stockpile, for public sale under Public Law 104-106.

1997 China: China initiates Program 973, to boost research and development of rare earths materials at the direction of Jiang Zemin.

1997 China v USA: Cumulative Chinese rare earth patents surpasses total U.S. patents (with China's first rare earth patent being filed in 1983).

1997 China: Jiang Zemin further defines China's industrial rare earth policy, stating "Improve the development and application of rare earths and change resource advantage to economic superiority"

1997 China: China's 4 highest ranking leaders establish and codify its 16-Character Economic and National Defense policy, essentially stating: 'all national economic policies are also national defense policies'.

1998 U.S. - China: During the acquisition and transfer of Magnequench to China Lockheed Martin sells GA Powders, a company that originated within Idaho National Laboratory and producer of rare earth magnet powders, to Magnequench: effectively transferring this U.S. National Laboratory technology to China.

1998 U.S.: In 1998 the entire remaining inventory of rare earths in the National Defense Stockpile are sold and shipped[xxiv], including all previously held reserves with the Department of Energy[xxv]

1998 China: China initiates construction of Neo Powder facility in China based on Magnequench patents, designs and equipment.

1998 China: China begins closing the U.S. Magnequench facility. Magneqench is the only U.S. producer of RE magnets used in Tomahawk Cruise Missiles and other defense and technology systems.

1998 USA: Unocal halts production at its California based Molycorp rare earth separation facility in connection with environmental issues and the discharges of mine tailings containing elevated thorium[xxvi]. Mine production continues. This is the only stand-alone rare earth mine in the U.S., possibly the world, at this time. The California facility never produced a commercial quantity of heavy rare earths[xxvii] and was never a vital part of the tech metal rare earth value chain (its geo-chemistry was deficient in heavy rare earths). All other rare earth production, including heavy rare earths used in the tech metal sector, came from byproduct and co-product production from some other primary commodity. These sources were eliminated from the supply chain due to a 1980 NRC regulatory change related to "source material". Today these resources continue to be mined but are disposed of to avoid NRC regulations, costs and liabilities.

1998 U.S. / France - China: Rhodia Incorporated announces the closure of its rare-earth separation plant in Freeport, TX, in conjunction with its plan to build a new separation plant in China. The new plant will be in Baotou, Inner Mongolia, China

1998 U.S. / France - China - U.S.: Rhodia signed an agreement with officials of the Baotou Rare Earth Development Zone, Inner Mongolia, to construct a production facility to produce rare-earth alloys and metal hydride powder for rechargeable batteries.

1999 China: China establishes its 3rd National Laboratory for rare earths in Mongolia – focused on Functional Materials Engineering[xxviii]

1999 USA: Publication of Cox Report by U.S. Congress that specifically outlined the ways and means that China uses to capture military and dual use technology,

including rare earths and nuclear weapons technology (this report was apparently ignored)[xxix]

1999 China v RoW: The Government of China announced it has stopped issuing new permits for rare-earth mining and limits on foreign investment in rare-earth processing plants and metallurgical operations. Foreign ownership of Chinese rare-earth mines was not allowed prior to these new restrictions[xxx].

1999 China: The Chinese government formed the Inner Mongolia Rare Earth Group Inc., for the purpose of integrating rare earth R&D, production and trade for the region

2000 China: Neo Powders begins production of rare earth metal powders

2001 China vs EU: Chinese rare earth patents surpass total EU patents

2001 China + RoW: China becomes a member of the World Trade Organization

2001 China: China establishes its 4th National Lab & Engineering Research Center for rare earths - focused primarily on Metallurgy[xxxi]

2002 China v U.S.: China completes closure of all U.S. Magnequench operations and physically relocates all machinery and remaining assets into mainland China

2002 USA: The Molycorp Mt. Pass mine is closed in 2002, in response to both environmental issues and lower prices for REEs[xxxii]

2004 U.S. – China: Bush Administration promotes off-shoring to China as a "good thing", including Commerce Department conferences designed to assist U.S. companies to "invest (read: establish facilities)" in China[xxxiii]

2004 USA - China: Apple begins manufacturing in China.

2005 RoW / China: The use of monazite, a low cost byproduct source of heavy rare earths, is fully discontinued in all leading economies in compliance with a 1980 NRC / IAEA regulatory change (with most leading nations in compliance by late 1980 or early 1990), environmental and liability cost associated with the companion element thorium[xxxiv]. Its use continues in China and other non IAEA signatory nations

2005 China: China establishes AMR Technologies in Canada. AMR Technologies is eventually renamed Neo Materials and acts as a front-company for China's interests. Neo Materials exist to implementation of China's industrial and defense policy

2005 China: China attempts to acquire the Molycorp Mt. Pass mine in California via its acquisition bid for Unocal

2007 China v U.S: China cuts off rare earths to W.R. Grace, forcing them to relocate in China.

2007 China v RoW: China enacts export tariffs on various rare-earth products to increase prices and discourage exports. The 10% tariffs were specific to essentially all exported rare earth products[xxxv]

2007 China v RoW: China begins rationing rare earth exports - sending a signal to global technology companies that only Chinese based companies have a guaranteed supply

2007 China vs Apple: In January 2007 Apple introduces the iPhone. Because the iPhone is highly rare earth dependent it is manufactured in China. High quality Chinese knockoffs are produced in China by mid-2007[xxxvi]. By 2011 Knockoff Apple stores begin popping up in China[xxxvii]. By 2016 the top 2 Chinese produced iPhone knockoffs, sold by Hauwei and Oppo, outsell Apple worldwide. By 2017 Huawei outsells Apple worldwide. By 2018 Chinese iPhone knockoff companies begin suing Apple for technology infringement (suggesting a new strategy of IP litigation to correspond with its mass accumulation of rare earth patents). This process of Chinese copyright and product infringement was already well established long before Apple transferred its manufacturing and technology to China. Because China controlled access to rare earths Apple had no alternative. This is a common story for all rare earth dependent technologies.

2008 China v RoW: China begins acquiring interests in non-Chinese rare earth mines

2009 China v RoW: Non-Ferrous Metal Mining Company acquires a majority stake in Lynas Corporation, currently the largest 'non-Chinese' rare earth producer outside China

2010 China v Japan: China cuts off Japan's rare earth supply – enforcing its signal to global technology companies that they must move to China if they want secure supply

2010 USA + RoW: Japan rare earth dispute with China sets of an exploration and speculation frenzy eventually resulting in the establishment of over 400 rare earth exploration mining companies.

2010 China v RoW: Prior to the Molycorp IPO and exploration frenzy various Chinese sources (available on line and in English) clearly stated that China's internal rare earth production capacity exceeded 300% of global demand[xxxviii]. This information was intentionally ignored and never included in any IPO documents (nor was it presentations to the U.S. Congress or Pentagon, with the exception of this author). Failure to include this sort of material information in public IPO documents amounts to fraud. To date no professional journals, research papers or industry, government or defense analysts provide this highly material information in any U.S. or 'western' publication (with the exception of this author). China's current official and published production number as of 2016 exceeded 300% of global demand[xxxix].

2010 -15 USA: Molycorp IPOs, the rare earth bubble collapses and Molycorp goes bankrupt. In the company's IPO documents it projected that 80% of its revenues would come from metallurgical capabilities the company did not have

and markets that did not exist. The company's "Mine to Magnets" business plan was dependent on heavy rare earth elements that could not be extracted from the deposit. The well-established geo-chemistry of the deposit did not conform with the IPO documents. Despite representations to the contrary, none of the heavy lanthanides were recoverable. The 2010 IPO was listed as the most profitable IPO of the year.

2011 China: Chinese National Development and Reform Commission, China's economic planning body, identified the development of the rare-earth elements as a strategic resource

2012 China: Forbes magazine discloses that Xi Jinping's family holds over $400 million in rare earth value chain assets

2012 RoW vs China: U.S., EU, Japan v China: US, Japan and the EU Governments filed a case against China at the World Trade Organization challenging its restrictions on REEs exports

2014 Row vs China: China loses its appeal on WTO case

2014 China vs Japan: Chinese rare earth patents surpass Japanese patents

2015 RoW v China: China scraps rare earth quotas, prices fall and Molycorp goes bankrupt (WTO case was a victory for China, playing out exactly as I argued to the Obama administration in early 2013)

2015 China v IP: China sues Hatachi over rare earth patents. Seven Chinese rare earth companies sue Japan's Hitachi Metals over NdFeB patents, claiming the firm violated international patent law and established unfair market barriers against China (considering China's massive accumulation of patents, this will become a powerful weapon against all non-Chinese rare earth IP).

2015 China v RoW: Chinese Ministry of Industry and Information Technology released its five-year plan for REEs, setting ambitious production and market-share goals for the domestic industry to meet by 2020.

2015 China vs RoW: China announces its "Made In China 2025" initiative. The government subsidized and state coordinated plan aims to "reduce" (read: replace) dependence on targeted high-value non-Chinese trade-goods, technologies and components, Specifically the plan aims to lower its dependence (read: establish independence and market dominance) of non-Chinese products, technologies and components in targeted technology sectors to below 40% by 2020 and 70% by 2025. The targeted technologies and market sectors are highly correlated with the majority of non-forestry and non-agricultural imports that make up China's balance of trade with the RoW. The targeted technologies and market sectors are biotech, medical equipment, aviation, agriculture (assume geo-engineering) and equipment, information technologies & services, automation and robotics, energy production, green energy systems and vehicles, advanced rail transportation,

advanced maritime shipping technologies and material science (read: more in the area of rare earths and other critical technology materials).

2015 USA: By this time the rare earth mining frenzy is a $10 billion black hole, ultimately resulting in the bankruptcy of over 300 rare earth mining companies, including Molycorp

2015 USA: By this time General Motors, Ford, Siemans, GE and most other large multi-national technology companies have moved component manufacturing, product lines, and / or entire industry divisions to China.

2015 USA: By this time the majority of all leading rare earth dependent wind, solar and battery manufacturing and technology is centered in China

2016 China v RoW: According to a China Chamber of Commerce of Metals, Minerals & Chemicals Importers & Exporters report Chinas official production quota for 2016 was 105,000 tons per year but total rare earth production exceeded 250,000 tons per year, putting so-called black market production at over 150,000 tons per year or at least 150% above official production. These official Chinese estimates call into question all existing and past estimates of Chinese rare earth production vs RoW produced by USGS, CRS, GAO, DLA and the Pentagon.

2016 China v RoW: China announces its One Belt, One Road initiative. The multi-trillion dollar program will link 68, mostly non-aligned, countries, totaling 4.4 billion people or about 40% of global GDP. This multi-national, multi-modal logistical system will establish hard-linked trade synergies and good will with many of the fastest growing population centers in the world.

2017 China v RoW: Chinese National Intelligence law requires "all Chinese organizations and citizens to support, cooperate and collaborate in [Chinese] national Intelligence work". Under this law it is legal duty for every Chinese organization and citizen to take actions that benefit China's economic and national defense interests, including Chinese students in our universities, working at our U.S. National Labs and for our defense contractors and technology companies. [xl]

2017 USA: 37 years after the 1980 U.S. Congressional Report on material dependence, noted above, President Trump signs an executive order requiring the USGS and Department of Interior to publish a list of critical materials. The new list includes 35 materials but lists "rare earths" as a single category (and scandium individually). If the rare earths were listed individually it would show that the U.S. is 100% import reliant for on 28 individual materials or 30% of the naturally occurring elements on the Periodic Table. The list only measures rare earth oxide dependence. Rare earth oxides have no significant technological or defense application; high value uses begin at the post oxide level. China is the only merchant producer (having unallocated capacity) of

rare earth metals. The U.S. is 100 percent dependent on China for all metallurgical and post-oxide forms of rare earths, directly or indirectly. The report fails to note this fact.

2107 China v. U.S.L The Molycorp Mt. Pass mine is sold to a consortium that includes Shenghe Resources, a Chinese company that has the exclusive right to sell all of the rare earths produced from the mine.

2018 Malaysia v. RoW: The Malaysian government puts Lynas's operating permit under review. The upper house in Malaysia is controlled by ethnic Chinese.

2018 China v. RoW: China announces that it plans to cut rare earth production by nearly 49 percent. This translates to zero Chinese rare earth exports to the rest of the world, signaling all remaining rare earth dependent technology companies to move manufacturing to China or face supply disruption / termination.

---------- over the period ----------

2010 – 18 Japan vs China: Japan has spent nearly $1.5 billion in its efforts to become more independent of China on rare earth resources, with no meaningful change in its level of dependence on China as it relates to metallurgy and other value added rare earth materials. In fact, most of the expanded resource production resulting from this investment passes through China for value adding and metallurgical processing (strengthening China's monopoly at the value added level).

2011 - 18 U.S. vs China: The U.S. Congress puts forward over a dozen bills intended to resolve the rare earth issue. Not one passes. All but two (put forward by this author) focus on the mining and resource issue, with no reference or depth of knowledge regarding the larger issues relating value chain production or the size and scale of China's structural monopoly

2013 - 18 Russia vs China: Russia invests $1 billion in rare earths to break Chinese dependence[xli]

2016 - 18 EU vs China: The EU plans to spend over $1billion to solve this problem and is committed to exploring multi-national cooperative solutions.

2008 - 18 USA vs China: To date the U.S. government has spent less than $150 million on solving this "bedrock national security issue (GAO)", with most of the money spent on grants for researching the potential for extracting rare earths from coal waste, recycling programs and seeking '*alternatives*' to rare earths (define "alternative": typically inferior to the preferred or best option). Extracting rare earths from coal ash or tailings is obviously cost prohibitive, considering that China gets over half of its rare earths as a no-cost byproduct from a single iron ore mine. A better option would be to utilize the legacy supply of heavy rare earths that continues to be mined and disposed of to avoid

the 1980 regulations that helped terminate the U.S. rare earth value chain. These historical resources were a high value and diverse, no-cost byproduct for many U.S. mines

2000 - 18 USA: Except for the short period of 2011 to 2015 (Molycorp's post IPO production run) the U.S. technology and defense industry have been 100% dependent on imported rare earth oxides.

2007 -18 USA: Since 2007 the U.S. technology and defense sector have been 100% dependent on China for imported rare earth metals, alloys and magnets: directly or indirectly. Regarding National Security, defense contractors can utilize Chinese rare earth metals under a narrow reading of Title 10's Critical Material clause. These Chinese base rare earth metals are typically converted into alloys and magnets by Japanese companies or U.S. '*fabricators*' before being purchased by U.S. defense contractors. In short, the procurement and production for all of our rare earth dependent weapon systems are 100% dependent on China

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[i] I must credit Nabeel Mancheri, Lalitha Sundarasan and S. Chandrashekar for setting a baseline to work off of in their publication "DOMINATING THE WORLD – CHINA AND THE RARE EARTH INDUSTRY" in conjunction with the National Institute of Advanced Studies, Bangalore India

[ii] China leads the world in quantum computing and quantum satellite technology (https://www.scmp.com/news/china/society/article/2110563/china-building-worlds-biggest-quantum-research-facility)

[iii] China leads the world in hypersonic research (http://www.airrecognition.com/index.php/focus-analysis-photo-report-aviation-defence-industry/aviation-defence-industry-technology/4174-china-building-new-wind-tunnel-for-hypersonic-aircraft-development.html)

[iv] China leads the world in next-gen nuclear energy, including work on nuclear powered drones and other weapons (http://mbir.org/analytic/molten-salt-reactors-program-china/)

[v] All Directed Energy Weapon systems require heavy rare earths.

[vi] China appears to be leading the world in the development and fielding of advanced weapons like the rail gun (https://www.popsci.com/china-navy-railgun-warship)

[vii] The Pentagon did not respond or make any inquiries when presented with this data[vii] earlier this year.

[viii] Rare earth oxides have no direct technology or defense applications.

[ix] Michael Pillsbury's "The Hundred-Year Marathon"

[x] https://en.wikipedia.org/wiki/Dalian_University_of_Technology

[xi] Rare Earth Frontiers: From Terrestrial Subsoils to Lunar Landscapes By Julie Michelle Klinger

[xii] https://www.nationalreview.com/magazine/2018/08/13/us-china-relations-who-lost-them/?mc_cid=c5f9108b8c&mc_eid=4fcf8cfcd6 & https://en.wikipedia.org/wiki/Dalian_University_of_Technology

[xiii] **Rare Earth Frontiers: From Terrestrial Subsoils to Lunar Landscapes By Julie Michelle Klinger**

[xiv] Rare Earth Information Center News, Ames Iowa Vol XX, December 1985 #4 (https://www.ameslab.gov/sites/default/files/RIC.News_.V20.N4.pdf)

[xv] This facility receives direct support from the Chinese government so technically it could also be defined as a National Lab

[xvi] Pages 10 – X=13 - https://www.gpo.gov/fdsys/pkg/GPO-CRPT-105hrpt851/pdf/GPO-CRPT-105hrpt851.pdf

[xvii] The Chinese government provides direct funding and support for this and 3 other national research centers, thus making these institutions the equivalent of our U.S. National Labs. Bautou could also be defined as a National Lab, bringing the total number of fully dedicated rare earth National Labs to 5 (not one U.S. National Lab is exclusively dedicated to rare earths – Ames Lab has many other non-rare earth budgetary obligations).

[xviii] Rare Earth Information Center News, Ames Iowa Vol XXIII, September 1988 #3 (https://www.ameslab.gov/sites/default/files/RIC.News_.V23.N3.pdf)

[xix] Rare Earth Information Center News, Ames Iowa Vol XXIV, June 1989, #2 (https://www.ameslab.gov/sites/default/files/RIC.News_.V24.N2.pdf)

[xx] "DOMINATING THE WORLD – CHINA AND THE RARE EARTH INDUSTRY" in conjunction with the National Institute of Advanced Studies, Bangalore India (pg 55 – 56)

[xxi] Rare Earth Information Center News, Ames Iowa Vol XXVI, September 1991 #3 (https://www.ameslab.gov/sites/default/files/RIC.News_.V26.N3.pdf)

[xxii] https://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/740495.pdf

[xxiii] https://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/740495.pdf

[xxiv] https://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/740499.pdf

[xxv] https://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/740495.pdf

[xxvi] https://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/740499.pdf

[xxvii] https://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/740499.pdf

[xxviii] "DOMINATING THE WORLD – CHINA AND THE RARE EARTH INDUSTRY" in conjunction with the National Institute of Advanced Studies, Bangalore India (pg 55 – 56).

[xxix] Pages 13 – 18 - https://www.gpo.gov/fdsys/pkg/GPO-CRPT-105hrpt851/pdf/GPO-CRPT-105hrpt851.pdf

[xxx] https://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/740499.pdf

[xxxi] "DOMINATING THE WORLD – CHINA AND THE RARE EARTH INDUSTRY" in conjunction with the National Institute of Advanced Studies, Bangalore India (55 – 56)

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