

**Testimony of Greg Autry, PhD
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On “The Mineral Supply Chain and the New Space Race”

Before the Committee on Natural Resources

Subcommittee on Oversight and Investigations

U.S. House of Representatives

December 12, 2023

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Introduction

Good afternoon, Mr. Chairman and honorable members of the Subcommittee. My name is Greg Autry, and I am a Clinical Professor and the Director of Space Leadership Policy and Business at the Thunderbird School of Global Management, a unit of Arizona State University. I also have an appointment as Affiliate Professor at ASU Interplanetary Initiative and as a Visiting Professor in the Institute for Security Science and Technology at Imperial College London. I serve as Vice President for Space Development at the National Space Society. I am testifying on my own behalf and the views expressed here are not necessarily the views of any organization.

My testimony will focus on the strategic and economic significance of extraterrestrial resource extraction in the context of China’s growing dominance of terrestrial mineral supply chains and aggressive plans for space development. I want to be clear that my remarks on that competition are in no way intended to disparage the admirable nation of China nor its hardworking people. I am excited by their passion for space and their scientific achievements in that domain. My criticisms are aimed entirely at the corrupt, nominally communist, dictatorship that exploits its own people and threatens our entire planet.

Context – We Have Set Ourselves Up for Failure

Dr. Ajay Malshe, a colleague of mine from Purdue and an expert in space manufacturing, sent me a note before this hearing. He wrote,

Strategic materials and manufacturing have always created new real wealth. America has handed that source of wealth to other nations, in every key sector from semiconductor to aerospace. Space is a new frontier and offers a second chance to reverse that error, and to go from consumers to makers. That process must begin with the supply of basic factor inputs, notably minerals.

Dr. Malshe’s comments underscore how appropriate it is for this important discussion to be held in this committee. As the 21st century unfolds, the United States finds itself being displaced on

the geopolitical and economic stage, by an aggressive and mercantilist competitor. A primary cause of the American decline that Professor Malshe observes has been the adoption, during the last century, of a Keynesian economic perspective which prioritized consumption above production and investment. We routinely hear Americans referred to as “consumers” and when our economy falls ill, the Rx is always fiscal and monetary stimuli designed to get American “consumers” back into the shopping malls, buying more Chinese goods, produced from a global supply chain of raw materials increasingly controlled by the authoritarian state.

This naïve economic strategy is like prescribing sugary cough syrup for pneumonia. It helps the financial press feel better for a couple of quarters, getting us through another election cycle; but it has bred staggering deficits and more recently it has pushed our economy toward stagflation. Worse, this process has funded and legitimized a genocidal regime and created a near peer military threat that requires ever increasing DoD budgets to defend against.

For all its many faults, the Chinese Communist Party harbors no delusions about the sources of national wealth and power. It has been strategically focused on resources, education, capital, and productive capacity. This is basically the system that Alexander Hamilton outlined in his 1791 report to Congress on Manufacturing. Using the “American System”, China strides across the world stage like a 19th century imperial power. While our economists worry about whether Americans will buy enough Chinese made stuff this holiday season, China is buying up mines, wells, and farmland in Africa, Latin America, and even in our own nation!

A couple of decades ago, most of the world’s rare earth elements were mined and processed in California at Molycorp’s Mountain Pass Mine, near the Nevada border. Then China began to aggressively strip mine and process these elements with no regard for the environment. Tim Maughan of the BBC writes about the resulting toxic environment that he found in Mongolia:

It’s a truly alien environment, dystopian and horrifying. The thought that it is man-made depressed and terrified me, as did the realisation that this was the byproduct not just of the consumer electronics in my pocket, but also green technologies like wind turbines and electric cars that we get so smugly excited about in the West. ¹

The CCP’s willingness to destroy the environment of occupied Mongolia for competitive advantage and to dump the resulting production far below market price, shuttered the U.S. mine. Having obtained a global rare earth monopoly, they jacked up pricing by double and triple digits. When the California mine reopened it was in a partnership with a Chinese State Owned Enterprise, under an agreement to ship all of the ore to China for processing. Meanwhile China threatens us with rare earth embargos as a tool to manipulate U.S. policy²; compelling DoD to fund a small domestic processing effort with taxpayer dollars.³ Seriously! You can’t make this up!

And this has been no Ricardian free trade paradise. As they gobbled their way across the globe, Chinese law prevented foreigners from owning or controlling resources inside of China. Now that we’ve awoken to how foolish we have been, we face a difficult supply chain problem.

Space Resources Offer Solutions

One answer to this problem is about 240,000 miles away. The surface of the Earth’s Moon is roughly equivalent to the entire continent of Africa. Having been formed some four and half

billion years ago in the collision of the Earth with a wayward protoplanet, our Moon shares many of the material properties of the Earth, with a few important differences. Measurements of the ratios of elemental isotopes, including oxygen and titanium found in Apollo samples confirm that the moon is composed of the same materials which form the Earth's crust.⁴ Much of what we use to live and prosper are found in abundance there. There are also things we may find only on the Moon.

Any good look at our celestial neighbor reveals thousands of asteroid impact craters and a few huge "basins" created by hits from supermassive planetesimals. These impactors were often composed of nickel-iron, platinum group metals, and even rare earth elements. Some of these will have interacted with molten lunar crust and water and may have been distributed into the Moon's crust or flowed into veins. Some of the cores may be solidly intact. Much of our minable mineral wealth that we extract from Earth is the result of similar past impacts.

Strategic Locations

The likelihood of buried metallic cores and concentrated infusions of minerals makes a few areas of the Moon strategically attractive. Most notably the Southern Polar regions of the Moon appear to contain a massive "metallic structure." Research of the Moon's unique gravitational anomalies, based on data from NASA's GRAIL mission, suggest an enormous mass concentration (mascon) is buried beneath the Moon's Aitken Basin. The study's lead author, Dr. Peter James of Baylor University, has suggested that the anomaly is, "a pile of metal five times larger than the Big Island of Hawaii."⁵

*This anomaly has a minimum mass of 2.18×10^{18} kg and likely extends to depths of more than 300 km. Plausible sources for this anomaly include metal from the core of a differentiated impactor or oxides from the last stage of magma ocean crystallization.*⁶

- James, et al., *Nature*

Of course, metallic asteroids can also be found in space. Thousands of them are found beyond the orbit of Mars and several near-Earth objects wander closer to our own planet. NASA's recently launched mission to the main belt asteroid Psyche will be the first to visit what we suspect is the massive metallic core of an unformed planet.⁷ It may contain more precious metals than have been mined in all of human history. The plucky spacecraft will beam back immensely valuable data from that metal world. There has been a great deal of enthusiasm in the press about how mining Psyche, or a near Earth object like Eros, could make us all billionaires.⁸ The reality is, of course, that if we learn to extract and return these materials, market prices would adjust significantly, but the more important point is that *everyone on Earth would indeed lead richer lives* without additionally impacting our environment.

The Moon's southern polar regions also appear to contain large reserves of water ice – which is indispensable for human occupation and operations. U.S. firms, such as Trans Astra, are looking at "mining" ice on the Moon for water as well as for the oxygen and hydrogen, rocket propellants that can be easily extracted from water with solar or nuclear power.

Mining on the Moon and asteroids, processing ore in situ, and delivering products to markets in space or on Earth are not easy or straightforward tasks. Space is a harsh environment. Partial or zero gravity, a cold vacuum, and constant radiation exposure demand new mining equipment,

processes, as well as a great deal of AI controlled automation. The energy required to move these materials to the orbits where they will be most useful can be very significant. Increasing our ability to deliver significant volumes of materials, or finished goods from orbit back down to the Earth will require new vehicles and reentry technologies.

Scrappy Entrepreneurs are Running America's Race with Limited Resources

Space is hard and a couple of high-profile space mining companies have already failed without returning anything to Earth or to their shareholders. As a scholar of technology entrepreneurship, I was not surprised by this, and it should not dissuade us from continuing to pursue this opportunity. Does anyone know recall who the first personal computer company was? It wasn't Apple. Who developed the smartphone? Again, not Apple. ⁹

Today, new companies are stepping forward and raising capital, including AstroForge of Huntington Beach, California and the U.K.'s Asteroid Mining Corporation. Both of these startups are focused on the return of platinum group metals (PGM), like iridium and palladium. PGMs have a number of critical industrial applications, particularly as catalysts in chemical processes, including the catalytic converters that reduce emissions from automobiles. Unfortunately, PGMs are among the rarest elements on Earth and their production is inconveniently dominated by Russia and South Africa. The U.S. Department of Energy has called for American leadership in PGM production.¹⁰ Space may offer a long-term path to that leadership position.

Not to be left behind, China has Origin Space, a nominally commercial firm located in Shenzhen. Origin Space has raised [CN¥150M](#) or approximately \$20million USD, making it better funded than its small, Western competitors.¹¹ The firm has already launched a test satellite, NEO-1.

It's About the Technology, Not Just the Minerals

These firms are popping up because the challenges of space mining are surmountable and the nation whose firms succeed will benefit from many positive externalities. The AI automated technologies required for mining on the Moon are highly applicable to Earth, where we must dig increasingly deeper to find new materials. Investment in one can provide American competitive advantages in both. Solar energy is abundant in space and increasing the efficiency of photovoltaic systems to power electric thrusters, perhaps using new classes of propellants, would benefit all manners of space transportation as well as increase our options for clean energy on Earth. Developing nuclear propulsion and nuclear power solutions for the lunar surface are key NASA objectives and would be of great benefit to the US Space Force in the future. Space mining can benefit from and assist with these nuclear solutions, which may someday return clean energy solutions for Earth.

Even if we never return minerals from the Moon, we will benefit from the effort to do so. We would not have the solar PV or fuel cells we enjoy today if it were not for space applications driving those technologies decades ago.¹² The hundreds of pounds of Moon rocks returned by Apollo astronauts, produced no direct revenues, but the First Space Race produced unexpected spinoffs that have transformed the world. Who knows what the 21st century equivalent of GPS or the Internet¹³ will turn out to be and how they will benefit our nation and everyone on Earth.

America Must Lead Here

It is important to note that this bright future only materializes for *everyone* if America takes the lead and space minerals are extracted and sold by private actors in a free market. We should not

expect Chinese state-controlled exploitation of the Aitken Basin mascon or the asteroid Eros to play out any differently than their terrestrial rare-earth monopoly or territorial aggression in the South China Sea have. We should expect the CCP to act without regard to anyone's rights, extract monopolistic rents, and then leverage their competitive advantage for political and military concessions from nations large and small. China's authoritarian leaders will, of course, cloak their aggressive space actions in the usual propaganda of greenwashing, insincere calls for international cooperation, and meaningless phrases extolling their supposedly virtuous nature.

Before you are tempted by calls for "cooperation rather than competition in space" or naïve suggestions that America should halt space development until we can ensure that space resources are equitably distributed for everyone on Earth, let's take a hard look at how that has worked on Earth. While the examples of the CCP's malfeasance and duplicity could overfill my testimony, let's consider the Galapagos islands. Darwin literally unraveled the mysteries of life on these starkly beautiful isles and the Ecuadorian government has worked hard to preserve this UN Natural Heritage Site. Satellite radio maps, from Hawkeye 360, show a constant ring of radio activity around the islands. These are hundreds of Chinese fishing and processing ships and their GPS transponders showing them just outside of Ecuador's economic exclusion zone. The mayor of Santa Cruz province describes their operations best:

They are killing the species we have protected and polluting our biota with the plastic waste they drop overboard. They are raping the Galapagos.

- Ángel Yáñez Vinuesa¹⁴

If simply hanging off the coast and "legally" killing everything that swims and polluting the Earth's most pristine ecosystem were not bad enough, satellite tracking of more subtle radio signals has revealed something more nefarious. Chinese trawlers routinely switch off their AIS transponders to "go dark" and then violate Ecuador's waters in order to move their floating slaughterhouses closer to shore.¹⁵ This has been going on for years in plain sight while China continues to promote internationalism and pretend it is a globally responsible actor. Any well-intended delay in U.S. efforts to develop space resources will simply put more of those resources into the hands of this rapacious regime.

Lastly, space also holds treasures we can't find on Earth. One of these is an isotope of Helium that contains just a single neutron. Helium 3 (³He) is extremely rare on Earth. Efforts to isolate ³He from Helium during natural gas refining yield only about a hundred parts per billion.¹⁶ However, it is believed to be found in relative abundance on the Moon, where the solar wind deposits it into the lunar regolith (dirt).¹⁷ Helium 3 has unique properties that enable several specialized Earth-bound applications including neutron detection, improved MRI imaging and cryogenic research. Most significantly it is hypothesized that ³He would be a preferable fuel for nuclear fusion reactors, providing emissions free energy with no residual radioactivity.

While the practicality of ³He as an energy source remains the subject of debate in the U.S., China is "all in" on the topic. Ouyang Ziyuan (歐陽自遠), the chief scientist for China's Lunar Exploration Program has stated that, "Each year, three space shuttle missions could bring enough fuel for all human beings across the world."¹⁸ Last year, China verified they have detected the rare isotope in samples returned from the Moon by their Chang'e 5 lunar mission.¹⁹

Humanity is at a pivot point. We are about to leave the cradle of our home planet to develop and populate the solar system. If we want that expansion to carry the angels of our better nature into the future and to benefit the Earth and everyone on it, America must lead. We must not permit a genocidal dictatorship to define the future of humanity nor gain further leverage over global supply chains.

Recommended Congressional Actions

1. Provide funding for R&D into dual use mining technologies that enable both space resource extraction and advanced terrestrial mining. Most importantly, support technologies for the detection of subsurface mineral deposits and AI enabled autonomous deep mining systems.
2. Support a *permanent and sustainable* presence on the Moon with our partners in the Artemis Accords and in constructive competition with the Chinese-Russian International Lunar Research Station.
3. Allocate additional funding to NASA's Science Mission Directorate for the continued exploration of lunar and asteroid resources.
4. Allocate additional funding to DOE and NASA's Space Technology Mission Directorate for the development of space power solutions including nuclear.
5. Develop follow on legislation to Commercial Space Launch Competitiveness Act (CSCLA) of 2015 and work with our partners in the Artemis Accords, in order clarify our interpretation of the Outer Space Treaty in language that supports a legal framework conducive to the development of space resources by private actors, including the security of exclusive operating areas in ways that will allow space mining and other "properties" to be transferable and collateralizable.
6. Clearly direct the United Space Force to prepare for the future protection of American commerce in cis-lunar space and on celestial bodies.

A quote often ascribed to Eleanor Roosevelt offers an appropriate closing,

The future belongs to those who show up.

¹ Maughan, Tim. "The dystopian lake filled by the world's tech lust", BBC, February 22, 2022.

<https://www.bbc.com/future/article/20150402-the-worst-place-on-earth> [last accessed Dec. 9, 2023]

² Navarro, Peter and Autry, Greg. *Death by China: Confronting the Dragon - A Global Call to Action*, 2010. Pearson. (p. 64).

³ Easley, Mikayla. "U.S. Begins Forging Rare Earth Supply Chain", *National Defense*, February 10, 2023.

<https://www.nationaldefensemagazine.org/articles/2023/2/10/us-begins-forging-rare-earth-supply-chain> d

⁴ Zhang, Junjun, et al. "The proto-Earth as a significant source of lunar material." *Nature Geoscience* 5.4 (2012): 251-255.

⁵ Goodrich, Terry. "Mass Anomaly Detected Under the Moon's Largest Crater", *Baylor University*, June 10, 2019.

<https://news.web.baylor.edu/news/story/2019/mass-anomaly-detected-under-moons-largest-crater> [last accessed Dec. 9, 2023]

⁶ James, Peter B., et al. "Deep structure of the lunar South Pole-Aitken basin." *Geophysical Research Letters* 46.10 (2019): 5100-5106.

⁷ <https://psyche.asu.edu> [last accessed Dec. 9, 2023]

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- ⁸ Carter, Jamie, "No, NASA's Asteroid Visit Next Week Won't Make Us All Billionaires", *Forbes*, October 2, 2023. <https://www.forbes.com/sites/jamiecartereurope/2023/10/02/no-nasas-asteroid-visit-this-week-wont-make-us-all-billionaires> [last accessed Dec. 9, 2023]
- ⁹ The first commercial personal computer was the Altair 8800 offered in 1975 by a New Mexico startup named MITS. The first smartphone was the Treo produced in 2002, by a company named Handspring.
- ¹⁰ "Achieving American Leadership in the Platinum Group Metals Supply Chain", U.S. Department of Energy, February 24, 2022 <https://www.osti.gov/servlets/purl/1871584> [last accessed Dec. 9, 2023]
- ¹¹ https://www.crunchbase.com/organization/origin-space/company_financials [last accessed Dec. 9, 2023]
- ¹² Autry, Greg. "Space policy, intergenerational ethics, and the environment." AIAA SPACE 2011 Conference & Exposition. 2011.
- ¹³ Autry, Greg. "Space policy, intergenerational ethics, and the environment." AIAA SPACE 2011 Conference & Exposition. 2011.
- ¹⁴ Gibbs, Stephen, "Huge Chinese fishing fleet accused of 'raping' Galapagos on industrial scale.", October 20, 2020. <https://www.thetimes.co.uk/article/huge-chinese-fishing-fleet-accused-of-raping-galapagos-on-industrial-scale-m08lxd60j> [last accessed Dec. 9, 2023]
- ¹⁵ Datta, Anusuya, "Satellite data nails Chinese fishing fleet near ecologically sensitive Galápagos Islands", *Geospatial World*, October 1, 2020. <https://www.geospatialworld.net/blogs/satellite-data-nails-chinese-fishing-fleet-near-ecologically-sensitive-galapagos-islands/>
- ¹⁶ Shea, Dana A.; Morgan, Daniel (22 December 2010). *The Helium-3 Shortage: Supply, Demand, and Options for Congress* (PDF) (Report). Congressional Research Service. 7-5700. [last accessed Dec. 9, 2023]
- ¹⁷ E. N. Slyuta; A. M. Abdrakhimov; E. M. Galimov (2007). "The estimation of helium-3 probable reserves in lunar regolith" (PDF). *Lunar and Planetary Science XXXVIII* (1338): 2175 [last accessed Dec. 9, 2023]
- ¹⁸ "Ouyang Ziyuan's Moon Dream Coming True," *China Daily*, July 26, 2006. <http://www.china.org.cn/english/scitech/175923.htm> [last accessed Dec. 9, 2023]
- ¹⁹ Whittington, Mark, "China has returned helium-3 from the moon, opening door to future technology", <https://thehill.com/opinion/technology/3647216-china-has-returned-helium-3-from-the-moon-opening-door-to-future-technology/> [last accessed Dec. 9, 2023]