

# THE MINERAL SUPPLY CHAIN AND THE NEW SPACE RACE

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## OVERSIGHT HEARING

BEFORE THE

SUBCOMMITTEE ON OVERSIGHT AND  
INVESTIGATIONS

OF THE

COMMITTEE ON NATURAL RESOURCES  
U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED EIGHTEENTH CONGRESS

FIRST SESSION

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Tuesday, December 12, 2023

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# OVERSIGHT HEARING ON THE MINERAL SUPPLY CHAIN AND THE NEW SPACE RACE

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Tuesday, December 12, 2023  
U.S. House of Representatives  
Subcommittee on Oversight and Investigations  
Committee on Natural Resources  
Washington, DC

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The Subcommittee met, pursuant to notice, at 10:19 a.m. in Room 1324, Longworth House Office Building, Hon. Paul Gosar [Chairman of the Subcommittee] presiding.

Present: Representatives Gosar, Rosendale, Collins, Westerman; and Stansbury.

Also present: Representatives Crane, Lamborn; and Kamlager-Dove.

Dr. GOSAR. The Subcommittee on Oversight and Investigations will come to order.

Without objection, the Chair is authorized to declare a recess of the Subcommittee at any time.

The Subcommittee is meeting today to hear testimony on the mineral supply chain and the new space race.

I ask unanimous consent the following Members be allowed to testify today with the Subcommittee, to give their testimony, and participate in the hearing from the dais: the gentleman from Arizona, Mr. Crane; and the gentleman from Colorado, Mr. Lamborn.

Without objection, so ordered.

Under Committee Rule 4(f), any oral opening statements at the hearing are limited to the Chairman and the Ranking Minority Member. I therefore ask unanimous consent that all other Members' statements be made part of the hearing record if they are submitted in accordance with Committee Rule 3(o).

Without objection, so ordered.

I now recognize myself for 5 minutes.

## **STATEMENT OF THE HON. PAUL GOSAR, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF ARIZONA**

Dr. GOSAR. Good morning everyone, and thank you to all the witnesses who have traveled such a long way to get here to testify on this important and somewhat new issue for the Subcommittee: the mineral supply chain and the new space race. The witnesses before us today are among the most pre-eminent intellects and entrepreneurs in their field, so I look forward to our discussion.

I understand that mining in space is not an issue that we hear about every day in Congress, but the fact is that the rest of the world, including some of our greatest competitors, like China and Russia, have started a new space race. This time it isn't a race to land someone on the moon for bragging rights. It is a race to establish a permanent, sustained space presence that will allow these

countries to tap into the vast resources in space, and subsequently control life on Earth in immeasurable ways.

Sadly, the governments of China and Russia have already completed a lap around the track, and the U.S. Government is seemingly unaware that the race has even started. Today's hearing aims to change that.

The effort to mine in space is driven by the immediate and projected global demands for minerals. Minerals including copper, lithium, cobalt, and dozens of others are integral to our modern way of life and technological innovation. There are increased obstacles to mining on Earth, so turning outwards reflects the unfortunate reality that space mining is more and more a necessity.

Mineral demand, driven by technological change, is exacerbated by climate goals and heavy-handed mandates from governments, including mandates from the Biden administration that force mineral-dependent electric vehicles on American consumers. As a result, global demands for critical minerals is projected to be more than doubled by 2030, and that is a conservative estimate.

Sadly, President Biden and his cronies have been making America increasingly reliant on our foreign adversaries for mineral supplies. The Biden administration is increasing mineral demand, with unprecedented government intervention into private markets, while at the same time doing everything in its power to strangle our domestic mining industry, including shutting down mining projects in my state of Arizona.

The actions by President Biden are further exacerbating America's dangerous reliance on China for critical minerals. At this time, the United States is import-reliant on China for 26 of the 50 minerals designated as critical by the USGS and the Department of the Interior.

China also dominates the mineral refining process, accounting for 85 to 90 percent of the global rare Earth element mine-to-metal refining. China's dominance of mineral supply chains on Earth presents a grave threat to America's national security and economic interests.

Additionally, the minerals integral to modern life typically come from resource-rich countries that are among the most egregious violators of human rights and the environment. For example, the Democratic Republic of Congo is associated with horrific environmental degradation and slave labor, yet it produces two-thirds of the world's cobalt. It is not a reach to say that a child in Congo is currently risking his or her life so that Americans can have unlimited access to smartphones and electrical vehicles.

As elected officials and Americans, members of the Committee cannot and should not turn a blind eye to where and how we get the minerals that have become essential to our modern way of life. The United States has a choice of how it responds to this exponential demand for minerals. We can increase support for domestic production where we are certain of responsible development practices, or allow foreign nations with unacceptable labor and environmental standards to dominate the global market. In order to maximize the national security, economic and environmental interests of the United States, prioritizing domestic mineral production is key.

While it is overdue for the United States to unleash domestic mineral development, America must also prepare to lead the world into the next frontier: space mining. As a country, we must accept that we are in the midst of a new space race, and we must take steps to secure the celestial mineral supply chain to provide a stable future for the United States and the free world.

Undoubtedly, we must also overcome major hurdles to make space mining a reality. This includes a transportation cost, logistical and technological hurdles, and the inherent uncertainty of space activity. However, if the United States can develop the ability to tap into these vast mineral resources on celestial bodies such as moons, Mars, and asteroids, the potential may in fact be limitless.

Eventually, the volume and the value of the space mining will provide immeasurable benefits to whoever controls the celestial mineral supply chain, and will prove disastrous for those who ignore it. China and Russia are committed to mining in space, and if we don't start preparing for the future of our resource development now, we will continue to find ourselves in a vulnerable position. Thus, America must take the necessary steps to secure our mineral supply chains by increasing domestic mineral development and leading the development of space mining activities.

I now recognize Ranking Member Stansbury for her 5 minutes.

**STATEMENT OF THE HON. MELANIE A. STANSBURY, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF NEW MEXICO**

Ms. STANSBURY. All right. Good morning, everyone, and thank you, Chairman Gosar and to my colleagues for this interesting hearing this morning. I am looking forward to hearing from our expert witnesses.

And I have to say, Mr. Chairman, when it came across my desk that we were going to have a hearing on space mining in the Natural Resources Oversight Committee, I did not have this on my bingo card this session. So, I am looking forward to the discussion today.

I agree with the Chairman that we absolutely have to address our critical minerals issues. We have had countless hearings in this Committee and other hearings across committees across Congress. We all know that this is a crucial national security issue, but I think that we have to also be realistic about the science, and I think we are going to hear a bit about that today.

Space mining, if it does transpire, is not in the immediate future. So, some of the issues that have been raised about our national security interests and supply chains cannot be resolved by pursuing this particular avenue. In fact, we know that many of the things that have to be pursued in the short term are right in front of us, and that is why the Biden administration has passed and put into place a whole-of-supply-chain effort to address our critical minerals with a strategy that they have put together, and that includes stockpiling the critical minerals that we do have access to. It means collaborations with our allies around the world where critical minerals are located. It means that, as international stewards, we ensure that the practices for sourcing those minerals

follow human rights protocols and environmental protection and, of course, that we help to promote a circular economy here on Earth, because we are, in fact, going to need these critical minerals in order to make this clean energy transformation that we are all undergoing right now.

So, it is important that we address these issues. And I do look forward to hearing from our folks today who are going to share about the near term and longer term aspirations of mining and space, what the technology looks like, what the ethical, moral, and legal considerations of all of that is. But we have to actually act here on Earth in the meantime.

There are also a number of issues that we have to be conscious of as we are pursuing these strategies. This is an interesting hearing to have in this Committee, which has primary jurisdiction over our public lands and waters, and works with our Indigenous Nations. And certainly, we want to make sure that we don't repeat the mistakes of the past as we pursue new technological options to pursue the sourcing of critical minerals.

But I do have to say it is the last week of Congress. We are about to gavel out in 2 weeks. We still haven't passed a real budget yet for the Federal Government. We still haven't actually addressed many of the big issues that are immediately in front of us. We have unsustainable leadership. There are fights in the halls happening. We had a Member expelled from Congress just 2 weeks ago. It is really a chaotic time. So, it is a bit strange, I think, for this Committee, which is an oversight committee, to be holding a hearing on space mining based on an aspiration that is possibly decades down the line, while our country is facing real crises.

So, while I am looking forward to hearing about this important issue, and I greatly appreciate the expertise of our witnesses who traveled here to come share today, it is a bit of an odd distraction from the most pressing issues that our country is facing right now. But I do look forward to the conversation.

Mr. Chairman, I turn it back to you.

Dr. GOSAR. I thank the gentlelady. I am always a believer you can chew gum and walk at the same time. I think we are going to find some interesting avenues in regards to our panel. Armageddon might be closer than you think.

I also want to waive on Ms. Kamlager-Dove for the panel, please.

Now I am going to introduce our witnesses. First, we have Mr. Eric Sundby, Co-Founder and CEO of TerraSpace, Executive Director of Space Force Association, Boerne, Texas; Dr. Greg Autry, Director and Clinical Professor, Space Leadership, Policy, and Business, Thunderbird School of Global Management, Arizona State University, Phoenix, Arizona; Dr. Moses Milazzo, Owner of Other Orb, Chief Scientist for NASA's Planetary Data Ecosystem, Flagstaff, Arizona; and Ms. Michelle Hanlon, Executive Director, Center for Air and Space Law, University of Mississippi School of Law, University, Mississippi.

Let me remind the witnesses that under Committee Rules, you must limit your oral statements to 5 minutes, but the entire statement will appear in the hearing record.

To begin your testimony, press the "on" button on the microphone.

We use timing lights here. To begin, you will see the green light. When it gets to the last minute, it turns yellow. And then finally, when it is red, you want to summarize up and finish up.

I now recognize Mr. Sundby for 5 minutes.

**STATEMENT OF ERIC SUNDBY, CO-FOUNDER AND CEO OF TERRASPACE, EXECUTIVE DIRECTOR OF THE SPACE FORCE ASSOCIATION, BOERNE, TEXAS**

Mr. SUNDBY. Good morning, Chairman Gosar, Ranking Member Stansbury, honorable members of the Subcommittee. I want to thank you for having us here today to speak on this issue of critical importance to our nation's security and standing on the global stage.

My name is Eric Sundby. I am the Co-Founder and CEO of TerraSpace, a mineral exploration company applying artificial intelligence to the mineral analysis process. I also serve as the Executive Director of the Space Force Association, a non-profit, non-partisan organization dedicated to supporting space force guardians and their families, and advocating for strong national and allied space power.

Humanity stands on the precipice of a new era, one that will be defined by space development and the utilization of space resources. Space holds an endless amount of opportunity for America, both economic and strategic. Yet, this opportunity is challenged by the Chinese Communist Party and its allies in Russia and a growing number of states, as China has launched the International Lunar Research Station Organization Initiative over the last year.

In 2015, the Strategic Support Force was established, providing a more organized structure for the space forces of the People's Liberation Army. It is through this institution that the China-manned space program is housed, which oversees all astronauts, operations, and space infrastructure development.

Lastly, in 2019, the Chinese Lunar Exploration Program Director equated the moon and other celestial bodies in the solar system to a series of island chains currently controlled by the Philippines and Japan, of which has been a point of contention in the CCP's illegal territorial expansion in the South China Sea.

Given actions here on Earth, the potential for great power competition in the space domain, particularly over space resources, is not on the horizon; it has already arrived.

In 2022, the United States Geological Survey, as you know, classified 50 mineral commodities that have no viable substitutes and are essential to the economic security of the United States. Many of these natural resources have been discovered on celestial bodies in our solar system, including on the moon and in the asteroid belt. Our ability to access and utilize these critical minerals here on Earth is threatened, as China currently controls 60 percent of production and 85 percent of processing capacity, according to analysis by the USGS and Natural Resources Canada.

This threat to our mineral supply chain calls for new and innovative ways at looking at resources from a national perspective, with space resources being front and center. This upcoming month, in January 2024, a company from my home state of Texas, Intuitive

Machines, will return America to the lunar surface for the first time since 1972. What is notable about this feat is that it is done by a commercial company. Its commercialization of access to space is what gives our country the strategic advantage. It is private enterprise that will provide new opportunities in the field of mineral discovery, mining, and processing, and will open up access to space resources.

I want to urge this Committee to investigate ways in which the government can encourage and lower entry barriers for technologies that can be applied to support the established Earth mining industry, while also enabling the discovery and access to resources off planet.

Various government agencies offer commercial companies the opportunity to contribute to research and develop technologies through programs such as Small Business Innovation Research grants, or SBIRs.

One area of improvement could be the USGS offering specific grants in support to companies developing technology to enable faster and less environmentally impactful methods of discovery and access of critical minerals, with an emphasis on such dual-use technologies as I mentioned earlier.

The use of space resources in alleviating the mineral supply chain here on Earth will not be an easy or quick task. I want to be clear about that. This must be a long-term strategic goal of the United States. Nevertheless, the development of technologies capable of operating in the harsh environment of space will enable further discovery and access to critical minerals here on Earth, such as those in existing mine sites, in more remote locations on land, and the deep seabed. Numerous start-ups and commercial companies are leading in this field, and are offering services in critical minerals, while exemplifying the pioneering spirit of American innovation.

President John F. Kennedy vowed that we shall not see space governed by a hostile flag of conquest, but by a banner of freedom and peace. It is up to the government to prioritize our nation's mineral supply chain, and open the way for such companies to carry this spirit forward into this new era. Thank you.

[The prepared statement of Mr. Sundby follows:]

PREPARED STATEMENT OF LANG ERIC SUNDBY, CO-FOUNDER & CEO OF TERRASPACE,  
EXECUTIVE DIRECTOR OF THE SPACE FORCE ASSOCIATION

Mr. Chairman, members of the subcommittee, I want to thank you for having us here to speak today on this issue of critical importance to our nation's security and standing on the global stage. My name is Eric Sundby, I am Co-Founder & CEO of TerraSpace, a mineral exploration company applying artificial intelligence to the mineral analysis process. I also serve as the Executive Director of the Space Force Association, a non-profit organization dedicated to supporting Space Force guardians and their families, and advocating for strong national and allied spacepower.

Humanity stands on the precipice of a new era, one that will be defined by space development and the utilization of space resources. Space holds an endless amount of opportunity for America, both economic and strategic. Yet, this opportunity is challenged by the Chinese Communist Party, and its allies in Russia and a growing number of states, as China has launched the International Lunar Research Station Organization initiative over the last year. In 2015, the Strategic Support Force was established, providing a more organized structure for the space forces of the People's Liberation Army. It is through this institution that the China Manned Space

Program is housed, which oversees all astronauts, operations, and space infrastructure development. Lastly, in 2019, the Chinese Lunar Exploration Program director equated the Moon and other celestial bodies in the solar system to a series of island chains currently controlled by the Philippines and Japan, of which has been a point of contention in the CCP's illegal territorial expansion in the South China Sea.

Given actions here on earth, the potential for great power competition in the space domain, particularly over space resources, is not on the horizon, it has already arrived. In 2022, the United States Geological Survey classified 50 mineral commodities that have no viable substitutes and are essential to the economic security of the United States. Many of these natural resources have been discovered on celestial bodies in our solar system including on the Moon and in the asteroid belt. Our ability to access and utilize these critical minerals is threatened, as China currently controls roughly 60% of production and 85% of processing capacity according to analysis by the USGS and Natural Resources Canada. This threat to our mineral supply chain calls for new and innovative ways at looking at resources from a national perspective, with space resources being front and center.

This upcoming month, in January 2024, a company from my home state of Texas, Intuitive Machines, will return America to the lunar surface for the first time since 1972. What is notable about this feat, is that it is done by a commercial company. This commercialization of access to space is what gives our country the strategic advantage. It is private enterprise that will provide new opportunities in the field of mineral discovery, mining, and processing, and will open up access to space resources. I want to urge this Committee to investigate ways in which the government can encourage and lower entry barriers for technologies that can be applied to support the established Earth mining industry, while also enabling the discovery and access to resources off planet. Various government agencies offer commercial companies the opportunity to contribute to research and develop technologies through programs such as Small Business Innovation Research grants or SBIRs. One area of improvement could be the USGS offering specific grants and support to companies developing technology that enable faster and less environmentally impactful methods of discovery and access of critical minerals, with an emphasis on such dual-use technologies as I mentioned earlier.

The use of space resources in alleviating the mineral supply chain here on Earth will not be an easy or quick task, I want to be clear, this must be a long-term strategic goal of the United States. Nevertheless, the development of technologies capable of operating in the harsh environment of space, will enable further discovery and access to critical minerals here on Earth, such as those on the deep-sea bed, existing mining sites, and in more remote locations on land. Numerous startups and commercial companies, including TerraSpace, are leading in this field and are offering services in critical minerals while exemplifying the pioneering spirit of American innovation. It is up to the government to prioritize our nation's mineral supply chain and open the way for such companies to carry this spirit forward into this new era.

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QUESTIONS SUBMITTED FOR THE RECORD TO MR. ERIC SUNDBY, CO-FOUNDER & CEO  
OF TERRASPACE, EXECUTIVE DIRECTOR OF THE SPACE FORCE ASSOCIATION

### Questions Submitted by Representative Gosar

*Question 1. How are space resources natural resources?*

Answer. From the widely accepted definition of the term *natural resources*, minerals from space are clearly classified as a natural resource.

#### **Explanation:**

The *Encyclopedia Britannica* defines a natural resource as “any biological, mineral, or aesthetic asset afforded by nature without human intervention that can be used for some form of benefit, whether material (economic) or immaterial” (*Encyclopedia Britannica*, 2023). From this widely accepted definition, minerals are clearly classified as a natural resource. The vast majority of minerals that are central to our way of life (save for some lab produced substances), come from geological processes that are outside of human intervention. These minerals naturally include the list of 50 critical minerals classified by the United States Geological Survey (USGS) last year as having no viable substitutes and play a central role in our national and economic security (Burton, 2022).

In terms of resources in outer space, found on planetary bodies such as the Moon and Mars, and asteroids abundant in the asteroid belt, all of these resources have been developed through processes afforded by nature without human intervention. Thus, space resources are definitively natural resources. Nevertheless, to understand space resources better requires a deeper dive into what resources are actually out there. The answer is rather simple, most of the natural resources found on Earth can be found in space. Asteroids, for example, are generally analyzed through viewing visual spectra through a telescope, or more simply stated by looking at the properties of the light reflecting off an asteroid's surface. This visual spectrum indicates what resources make up the majority of the asteroid. Through decades of research into asteroid samples which have fallen to Earth, we have come to the understanding that asteroids are generally geologically homogenous, meaning they are largely made up of the same material. Many of the critical minerals on the USGS's list can be found in the asteroid belt, including platinum, palladium, nickel, cobalt, rhodium, ruthenium, the list goes on and on. So too are other useful elements found in abundance, such as iron.

Planetary bodies, on the other hand, are trickier. Much like with the Earth, these bodies can be heavily geologically diverse. Some contain thick layers of regolith (a layer of loose material such as dust and rocks, lacking organic material, which covers a more solid planetary surface). The Moon is a perfect example of a planetary body with natural resources near Earth. Although much is known about the Moon's geological and mineralogical makeup, there remains a lot we have yet to learn. Lunar regolith has been determined to range from 4–5 meters in the mare (plains) regions to 10–15 meters in the highland regions (Heiken, et. al., 2005). The Apollo missions, particularly Apollo 15, 16, and 17, used drill cores to collect deeper samples rather than scooping surface regolith and collecting surface rocks; however, the deepest core collected was a mere 2.92 meters, not going deeper than the regolith (Meyer, 2007). While we do have a good understanding of what mineral deposits and their characteristics are below the regolith, based on LIDAR (light detection and ranging), ground-penetrating radar, and other remote sensing technologies, we have yet to get physical samples which would give an exorbitant amount more of data. On Earth, the mineral exploration process is more complex, with core drilling and logging of mineralogical information and data from these cores central to the process. Mineral exploration at mine sites requires the acquisition of many core samples at varying depths, most in the tens to hundreds of meters. These samples are then analyzed by geologists to determine the presence of minerals being sought (Epiroc, 2023). While this process is common in the mining industry, the development of technologies to discover specific mineral makeups of regions on planetary bodies has been limited to exploration programs through NASA and other government funded programs in various countries, and have not been scaled to enable substantial mineral exploration off planet.

From these facts it is clear that space resources are natural resources. Yet, the ability to explore deeper for specific mineral deposits on planetary bodies has lacked substantial developments—which should be encouraged by the government, and can benefit the country economically, strategically, and environmentally.

*Question 2. How can the House Committee on Natural Resources help America secure the celestial mineral supply chain?*

**Answer. Short Answer—**

The House Committee on Natural Resources has jurisdiction over the topic of space resources, as it oversees the USGS which conducts research and publication on this field. The committee can take five key actions to move the ball forward on technological innovation and development of space resources which will help America secure the celestial mineral supply chain.

**Action Plan—**

I would like to propose five actions on how it can help America secure the celestial mineral supply chain:

1. Place space resources as a “Mission Area” of the USGS.
  - a. *While space resources will play directly into the “Energy and Minerals Mission Area” once the field is matured, space resources currently require a separate focus to help develop the field.*
2. Increase funding to the Astrogeology Science Center at USGS.
  - a. *The Astrogeology Science Center is the primary organization within USGS that oversees planetary science, mapping, and geologic research; however, it is arguably lacking in funding that would enable it to cooperate and*

*coordinate with innovative start-ups and private commercial companies developing new technologies in the field. Further, the Center could increase its research into mapping and surveying, and mineral exploration for the public's knowledge, while also increasing its scientific research output.*

3. Develop an open-topic SBIR or similar grant program. This program can include a track focused on space resources, which encourages commercial companies in the development of dual-use technologies that will enable eventual access and utilization of space resources.
  - a. *Unlike many other government organizations (including the Department of Defense, Department of Energy, NASA, and others), the USGS lacks a substantial private sector grant program to encourage innovation in technologies that will benefit the further access to critical minerals designated by the USGS.*
4. Require a yearly report to the Committee from USGS on the state of space resources technologies, scientific developments in the field, and discovery and mapping of new resources.
  - a. *By providing the Committee with frequent updates on developments in the field of space resources, members of the House will be increasingly informed about the realities of the field, and how and when such resources may alleviate Earth-based reliance of certain key minerals. Further, the Committee will be informed through this report on the actions of foreign states, including adversaries, in the field of space resources.*
5. Form a Congressional Advisory Commission to examine and make recommendations with respect to the near-term and long-term development and uses of space resources, and its impact on the national security and economic security of the United States.
  - a. *As this issue has largely been left out of discussion within Congress, this Commission could present Congress with a detailed report with a defined realistic timeline and specific policies the government should take in approaching the issue of space resources. The Commission may provide a comparative analysis on the use of space resources to offset environmental damage on Earth, as well as the developments of foreign states, including adversaries, on this topic. This Commission can also provide annual reports to Congress on technical, financial, and strategic progress made in the field.*

**Explanation:**

Despite some confusion, the Committee indeed has jurisdiction over the topic of space resources, first and foremost due to its oversight of the United States Geological Survey which has been given purview over the field of study. Since 1960, the USGS has managed the Astrogeology Science Center, previously classified as the Astrogeologic Studies Group and the Astrogeology Research Program, which was originally formed to assist in Lunar and planetary mapping, Apollo astronaut geological training, and other space focused research (Wilhelms, 1993). According to the USGS, this internal organization is explicitly tasked with the following mission statement: “To help humanity understand our solar system by maximizing the scientific and technological return from planetary missions through scientific research, software development, and the creation of spatial data products and standards” (U.S. Geological Survey, 2023). The Astrogeology Science Center further serves as “a national resource for the integration of planetary geoscience, cartography, and remote sensing” (U.S. Geological Survey, 2023).

Now that it is established that the House Committee on Natural Resources has jurisdiction over this topic. Regarding space resources, the House Committee on Natural Resources has a massive responsibility before it, one that has the potential to change the course of our entire species. While such a statement may be seen as hyperbolic to some, it is clear that the abundance of resources available in near-Earth space can be utilized for the betterment of humanity, and the security of our country on the global stage. Through the five actions listed above, the House Committee on Natural Resources can raise the discussion of the important impact that space resources will have on the country outside of the laboratory and into the public forum. If we are to advance as a nation, we need to look forward, realistically, towards the positive economic uses of outer space from a more public level.

### Questions Submitted by Representative Lamborn

*Question 1. What are the opportunities and barriers to greater coordination and investment in space resources research within industry?*

Answer. Regarding coordination and investment in space resources research within industry, there are a few barriers and opportunities that present themselves. Barriers include the failure of previous space resources focused firms and subsequent investor hesitancy in the field, the SBIR program not focusing enough on mining/space resources adjacent technologies, and a general lack of understanding on the topic in wider society. Opportunities that exist include the Artemis Program's strength of bringing space resources into a mainstream discussion and its requirements for technology in the field, the development of dual use technology that helps the existing mining industry while also benefiting the development of space resources, and lastly the application and adaptation of existing technology within industry to support space resources which can open up establish companies into the new market.

#### **Explanation:**

Innovation through the private sector is one of America's greatest strengths, but it also faces a large hurdle before it. Specifically, for space resources, there exists a few barriers that prevent greater coordination between firms and investment into companies in the field. One of the primary barriers to investment in space resources is the previous failure of companies such as Planetary Resources, which was subsequently acquired by the software company ConsenSys. Because the space resources market has not materialized within a healthy time frame, investors are hesitant to throw money at new companies in the field, and rightfully so. Since 1982, the government has coordinated the Small Business Innovation Research (SBIR) grant program, which has provided many startups with funding and government partnerships that attract investment. These SBIR programs have become part of the very fabric of American innovation, and in many cases are a requirement by investors for a startup to have before they commit their angel or venture capital money to the young firm.

The challenge here is that industry has become accustomed to reliance on small government grants, which are meant to prove out basic innovative technology. With a lack of space resources or peripheral related technology being strongly represented in SBIR programs, many space resources companies find themselves competing and working on grants that do not assist in developing their firm's technology, and thus slow their ability or outright stop them from creating a commercially viable dual-use or space-focused technology for access or utilization of space resources.

A final barrier to coordination is the lack of understanding by the public, the mining industry, and the wider aerospace sector of the abundance of what space offers in terms of critical minerals and natural resources. This issue is somewhat more challenging than the others, as it requires educating various markets and their leadership, and requiring clarity of understanding the near-term and long-term issues related to space resources and returns on investment.

With discussion of barriers to greater coordination and investment in space resources within industry being somewhat heavy, it is important to point out the numerous positive opportunities that industry presents. First and foremost, the existing Artemis Program led by NASA requires a multitude of newer technologies to sustain human operations on the lunar surface. For the Artemis Program and subsequent presence on the Moon to be successful and sustainable, the access and utilization of space resources will be centrally necessary in achieving this goal, both for construction of shelter, forming landing pads for spacecraft (in order not to kick up massive amounts of regolith), and the development of rocket fuels and potential nuclear reactor fuels. These necessities drive up the government's reliance on private companies' space resources technologies, which in turn can drive investor's interest in investing in such companies.

Another opportunity for greater coordination and investment into space resources presented by industry is the development of dual use technologies. While the phrase *dual use* can be seen as a buzzword, there exists very real opportunities with such technology. For example, the process of mineral exploration is human-intensive and requires many core samples to be taken at mine sites. Some dual use technologies being developed currently allow for a more autonomous process of analyzing minerals, as well as new technology that allows drill bits to core deeper both on Earth and off-planet.

An opportunity also exists in seeking out existing and developed technology that has not been introduced into the field of space resources, or thought to be utilized

in such a manner. Many inventions and technologies that are in use on Earth will be needed when accessing and utilizing resources in space. Through treating space resources as a priority, existing industry can be brought into the fold to assist in the development of the nascent space resources market.

*Question 2. What other gaps are we missing when we think of mining operations in space, and the need for a supply chain to bring those back or refine them in space?*

Answer. There exists a handful of gaps in mining operations in space, and particularly in the supply chain. These gaps include the creation of more powerful energy sources, autonomous capabilities to explore and prospect for minerals, and the further refining of extraction techniques that are not commonly used on earth. However, it is important to note that much of these gaps are being investigated by startups and innovative companies with promising answers.

**Explanation:**

Mining in general seems to be an afterthought of most in society. There is a common perception that if we are to use electric vehicles and batteries in our grid system that we will lower environmental impact. While electric vehicles and electrification in general is largely a positive move for lowering carbon emissions, it is extremely questionable that the current environmental and human impact of mining is truly offsetting our impact on the planet (International Energy Agency, 2021). While the International Energy Agency's report on the role of critical minerals in clean energy transitions does note steps to mitigate the environmental impacts made by mining, as long as humanity exists, we will require resources to survive. Unfortunately accessing many of these minerals has negative impacts on our natural environment. Therefore, we require a levelheaded and realistic approach to the process required to access critical mineral resources beyond our home planet, for the benefit of our home planet. While this vision is one that will not be achieved in a short time, it is one that needs to be planned for strategically and worked towards diligently.

When thinking about mining in space, and particularly the supply chain necessary to bring back such minerals or refine and use them in space, many frequently throw their hands up in dismay at the complex physics and orbital mechanics involved. Others hold starry eyed visions of an expanding human species beyond this planet that will explore and develop the cosmos. Both groups have much merit, and admittedly, I find myself in the latter camp (albeit grounded by reality).

Although the physics involved is complex, the reality is that accessing and utilizing space resources is entirely possible, and in my view necessary. Where the 'grounding in reality' I mentioned earlier comes from, is the complex supply-chain processes that will need to be developed to enable space resources to be brought to the Earth market, or at least used in developing in-space economies.

1. First, a super-heavy lift launch vehicle will need to be certified and produced at scale. This challenge is something SpaceX has taken on with their Starship and Super Heavy systems (SpaceX, 2023). Others, including Blue Origin are developing their own launch platforms to rival Starship as well. There exist concerns over Starship's need of refueling, but nevertheless, as engineering processes go, the system will see new iterations with potential propulsion designs that decrease the need for frequent refueling. Only time will tell. Starship, and other super heavy lift launch platforms have been noted as being useable for the transportation of samples and minerals extracted in space (O'Callaghan 2021).
2. Second, the creation of more powerful energy sources and storage capability will assist in increasing the operational capacity of rovers, drills, etc.
3. Third, a stronger on-site (and most likely autonomous) capability to explore and prospect for minerals is needed. This capability can be coupled with existing remote sensing technologies.
4. Fourth, extraction techniques need to be refined, as some of those proposed are not used on Earth as they uniquely navigate the extreme environment space presents.

These gaps in the supply chain are understood by many in the field of space resources. Some of these gaps have entire books written about them, but often are not consulted by policy and lawmakers because of an all too frequent (and very wrong) belief that the development of space does not benefit the Earth.

Nevertheless, there exists an important gap in the formation of the supply chain for near future mining operations of planetary bodies: one that has of yet been answered by theoretical concepts or early-stage technologies. This gap is that of

mineral exploration and prospecting, as mentioned briefly before. Planetary bodies have not been explored similarly to how we search for minerals on Earth. Probes have used remote sensing, and for the Moon, the Apollo astronauts took samples from the surface. If we want to explore for minerals in space as we do on the Earth, we must develop technologies and capabilities that allow us to understand the economic viability of extracting resources from a planetary body such as the Moon. To achieve this capability requires deeper core samples, and more sophisticated mineral analysis equipment and sensors, including the need for autonomous systems, to be able to determine if a site on such a planetary body is worth mining—just as we do here on Earth. Remote sensing and surface sampling just won't cut it. This is a key gap that will need to be fixed as the Artemis Program, and the equivalent International Lunar Research Station Organization being developed by China and Russia, begin to populate the lunar surface and search for critical minerals. The development of capabilities such as autonomous mineral exploration rigs will help in the discovery of new mine sites off world, bridging a key gap in the space resources supply chain.

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Dr. GOSAR. Thank you very much, Mr. Sundby. I now recognize Dr. Autry for his 5 minutes.

**STATEMENT OF GREG AUTRY, DIRECTOR AND CLINICAL PROFESSOR, SPACE LEADERSHIP, POLICY, AND BUSINESS, THUNDERBIRD SCHOOL OF GLOBAL MANAGEMENT, ARIZONA STATE UNIVERSITY, PHOENIX, ARIZONA**

Dr. AUTRY. Good afternoon, Mr. Chairman, Ranking Member, and honorable members of the Committee. I am testifying on my own behalf. The views expressed here are not the views of any organization. I will speak on the specific strategic significance of extraterrestrial resource extraction in the context of China's competitive space development agenda. My remarks are not intended to disparage the people of China. They are aimed at the corrupt dictatorship that exploits its people and threatens our planet.

I also appreciate the non-partisan nature of space policy.

Seeing this hearing, Dr. Ajay Malshe, a colleague of mine from Purdue, sent me a note. 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 semiconductors to aerospace. Space is a new frontier, and offers a second chance to revise that era and to go from being consumers to makers. That process must begin with the supply of basic factor inputs, including minerals."

Dr. Malshe's comments underscore how appropriate it is for this important decision to be held now in this Committee. Dr. Malshe's observations are driven by a Keynesian economic perspective which prioritizes consumption above production. When our economy slows, the prescription is always stimulate the consumers into the mall. This has funded a dangerous military dictatorship and pushed us into stagflation.

The Chinese Communist Party, on the other hand, harbors no delusions about the source of national wealth and power. It is laser-focused on capital, resources, and productive capacity, as we once were. China buys mines and lands in Africa, Latin America, and even in the United States, and then blocks others from buying theirs.

Earth's moon, on the other hand, is roughly the size of Africa, is covered with impact craters, and some of these are composed of nickel, iron, and platinum group metal asteroid cores. Analysis of NASA data suggests that an enormous mass concentration is buried near the moon's south pole. Dr. Peter James of Baylor University describes that as a pile of metal five times larger than the Big Island of Hawaii.

NASA's Psyche mission will be the first to visit a metal asteroid. The press has suggested that mining Psyche will make us all billionaires. The reality is that when we do learn to mine these materials, market prices will adjust, but everyone on Earth will lead richer lives.

AstroForge of Huntington Beach, California is focused on the return of important platinum group metals that are rare here on Earth. Trans Astra is planning on mining ice near the poles for water, as well as oxygen and hydrogen for rocket power. Origin Space of Shenzhen, China, on the other hand, has raised 150 million yuan, and China's moon czar is all in on the idea of extracting helium 3 from lunar regolith for fusion power.

The Chinese know that space mining challenges are surmountable and will produce positive externalities, and they are working on it now. Mining on the moon and asteroids, processing ore and delivering products to our markets in space or Earth is not simple and will not happen quickly. It will demand advances like AI-controlled mining equipment, automation, and nuclear power solutions. Technological spin-offs from the first space race enriched our nation and transformed the world. Technologies required for space mining will also be applicable to Earth.

I know some will suggest that we halt space development until we deal with every problem on Earth, or until we can ensure that resources are equitably distributed for everyone on Earth. I appreciate that. But the CCP will continue without regard to rights or

rules, and they will leverage their monopolies against nations large and small. Any delay in America's development of space resources, no matter how well intended, will leave the field to that rapacious regime.

I have some recommended actions for Congress.

Provide additional R&D funding for dual-use technologies that enable both space resource extraction and advanced terrestrial mining, including the detection of subsurface mineral deposits and AI-enabled autonomous deep mining systems.

Support a permanent and sustainable presence on the moon with our partners in the Artemis Accords.

Appropriate additional funding to NASA's Science Mission Directorate for continued exploration of lunar and asteroid resources.

Appropriate additional funding to DOE and NASA's Space Technology Mission Directorate for the development of nuclear space power solutions.

Further clarify our interpretation of the Outer Space Treaty and language that supports a legal framework conducive to the development of space resources by private actors, including the security of exclusive operating areas and ways that will allow space mining to be transferrable and collateralizable.

Clearly direct the U.S. space force to prepare for the future protection of American commerce in cis-lunar space and celestial bodies.

Let me close with a quote often attributed to Eleanor Roosevelt that I think speaks to the topic of why we should do this now. She said, "The future belongs to those who show up." Thank you.

[The prepared statement of Dr. Autry follows:]

PREPARED STATEMENT OF GREG AUTRY, PHD, DIRECTOR OF SPACE LEADERSHIP,  
POLICY, AND BUSINESS, THUNDERBIRD SCHOOL OF GLOBAL MANAGEMENT,  
ARIZONA STATE UNIVERSITY

### **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 extra-terrestrial 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 increasing 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.<sup>1</sup>*

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. policy;<sup>2</sup> compelling DoD to fund a small domestic processing effort with taxpayer dollars.<sup>3</sup> 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

<sup>1</sup>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]

<sup>2</sup>Navarro, Peter and Autry, Greg. Death by China: Confronting the Dragon—A Global Call to Action, 2010. Pearson. (p. 64).

<sup>3</sup>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>

composed of the same materials which form the Earth's crust.<sup>4</sup> 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."<sup>5</sup>

*This anomaly has a minimum mass of  $2.18 \times 10^{18}$  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.*<sup>6</sup>

—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.<sup>7</sup> 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.<sup>8</sup> 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.

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

<sup>5</sup>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]

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

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

<sup>8</sup>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]

### **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.<sup>9</sup>

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.<sup>10</sup> 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 CNY150M or approximately \$20 million USD, making it better funded than its small, Western competitors.<sup>11</sup> 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.<sup>12</sup> 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 Internet<sup>13</sup> 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

<sup>9</sup>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.

<sup>10</sup>"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]

<sup>11</sup>[https://www.crunchbase.com/organization/origin-space/company\\_financials](https://www.crunchbase.com/organization/origin-space/company_financials) [last accessed Dec. 9, 2023]

<sup>12</sup>Autry, Greg. "Space policy, intergenerational ethics, and the environment." AIAA SPACE 2011 Conference & Exposition. 2011.

<sup>13</sup>Autry, Greg. "Space policy, intergenerational ethics, and the environment." AIAA SPACE 2011 Conference & Exposition. 2011.

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.*<sup>14</sup>

—Ángel Yáñez Vinueza

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.<sup>15</sup> 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 (<sup>3</sup>He) is extremely rare on Earth. Efforts to isolate <sup>3</sup>He from Helium during natural gas refining yield only about a hundred parts per billion.<sup>16</sup> However, it is believed to be found in relative abundance on the Moon, where the solar wind deposits it into the lunar regolith (dirt).<sup>17</sup> 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 <sup>3</sup>He would be a preferable fuel for nuclear fusion reactors, providing emissions free energy with no residual radioactivity.

While the practicality of <sup>3</sup>He as an energy source remains the subject of debate in the U.S., China is “all in” on the topic. Ouyang Ziyuan, 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.”<sup>18</sup> Last year, China verified they have detected the rare isotope in samples returned from the Moon by their Chang’e 5 lunar mission.<sup>19</sup>

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.

<sup>14</sup>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]

<sup>15</sup>Datta, Anusuya, “Satellite data nails Chinese fishing fleet near ecologically sensitive Galapagos Islands”, Geospatial World, October 1, 2020. <https://www.geospatialworld.net/blogs/satellite-data-nails-chinese-fishing-fleet-near-ecologically-sensitive-galapagos-islands/>

<sup>16</sup>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]

<sup>17</sup>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]

<sup>18</sup>“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]

<sup>19</sup>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]

### 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.*

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QUESTIONS SUBMITTED FOR THE RECORD TO DR. GREG AUTRY

### Questions Submitted by Representative Gosar

*Question 1. How are space resources natural resources?*

Answer. I'd be hard pressed to understand how space resource would be "unnatural." They are not fabricated by humans. They were created by God or nature through the same natural process that created the Earth and everything in our solar system. In fact, many of the metals and minerals we mine from the crust of the Earth were deposited there by the impacts of asteroids in the past. The heaviest materials present in the original formation of the Earth sunk to the core and are inaccessible to us.

#### **NASA routinely refers to space resources as "natural resources." Examples:**

On their website NASA defines In-Situ Resource Utilization (ISRU) as follows "ISRU is the harnessing of local *natural resources* at mission destinations, instead of taking all needed supplies from Earth, to enhance the capabilities of human exploration." (emphasis on "natural resources" added) <https://www.nasa.gov/mission/in-situ-resource-utilization-isru/>

Another article is entitled "NASA Challenge Seeks Ways to Use Mars' Natural Resources for Astronauts." <https://www.nasa.gov/news-release/nasa-challenge-seeks-ways-to-use-mars-natural-resources-for-astronauts/>

#### **Academics routinely refer to space resources as "natural resources." Examples:**

Coffey, Sarah. "Establishing a legal framework for property rights to natural resources in outer space." Case W. Res. J. Int'l L. 41 (2009): 119.

Tronchetti, Fabio. The exploitation of natural resources of the Moon and other celestial bodies: a proposal for a legal regime. Vol. 4. Martinus Nijhoff Publishers, 2009.

Jakhu, Ram, and Maria Buzdugan. "Development of the natural resources of the moon and other celestial bodies: economic and legal aspects." *Astropolitics* 6.3 (2008): 201-250.

**USGS believes that space resources are “natural resources” under its domain. Examples:**

*Surveying natural resources was the key job Congress gave the USGS when it was created on March 3, 1879 . . . In 2017 we published a study that showed that the methods the USGS uses on Earth can be applied to asteroid resources with only modest modification.* <https://www.usgs.gov/index.php/news/usgs-prepares-assess-resources-moon>

*“The USGS realized that our congressional mandate to assess natural resources extends to space” Kestay said. At this time, the USGS does not have a funded program to conduct full-scale assessments of space resources. “But we are anticipating that the USGS may be directed to do so soon, and we are taking a number of steps to be prepared for that possibility,” he said. (Space News quoting Lazlo Kestay, a USGS research geologist)* <https://www.space.com/41707-space-mining-usgs-resource-survey.html>

**Relevance to the Natural Resources Committee**

I see no reason why the location of resources would change their nature or affect the relevance of this committee’s oversight over them. The fact they would be accessed via rockets and spacecraft doesn’t change the nature of the material. We would not insist that because minerals are transported by rail, ship, or truck that only Transportation & Infrastructure Committee could discuss those materials. The technology of the mode of transport is far less relevant than the economic and strategic importance of these natural resources.

*Question 2. How can the House Committee on Natural Resources help America secure the celestial mineral supply chain?*

Answer. As I stated in my testimony I recommended six items, not all of which are directly within the Natural Resources Committee’s portfolio but for which the committee could take an active role in leading and supporting. My first recommendation is directly within the committee’s jurisdiction, and I believe that there funds in USGS and other buckets that could be applied to this important task.

*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.*

Additionally, appropriate the funding that Dr. Kestay is referring to above. As he notes, the Astrogeology Science Center is ready and waiting to do this work.

I also want to be clear that we are not talking about “billions of dollars” as was oft repeated in the hearing. NASA is spending billions to get us back to the Moon. DoDo is spending billions on space capabilities. Natural Resources can leverage those huge expenditure and accomplish a great deal with the judicious application of a few \$million. China is certainly far more than that to beat us to these resources.

Form an Advisory Commission to the Committee or an Advisory Committee to USGS on how best to utilize funding and resources and most importantly coordinate with NASA and DoD lunar efforts. Appoint individual to that body that understand the science, engineering, economics, business aspects of space mining. Ensure there are individuals who have experience working with NASA and DoD leadership.

**Questions Submitted by Representative Lamborn**

*Question 1. What are the opportunities and barriers to greater coordination and investment in space resources research within academia?*

Answer. I am convinced there are significant opportunities for the coordination of research and investment in space resources within academia. Firstly, there are a number of academic institutions already doing this work, albeit on a shoestring budget. Among these:

- The Colorado School of Mines
- The University of Central Florida
- Purdue
- Arizona State University
- University of Alabama at Huntsville

These schools and others could use funding or the opportunity to access USGS grants. Some grants for technology development and the like at USGS could perhaps be expanded to allow for space related applications. I think this is particularly important in the “dual use” category where work done on a space related project, such as automated assaying equipment or AI enabled mining robotics, would produce benefits for both space and terrestrial applications. This addresses the relevance to “problems here on Earth” questions.

NASA is already working with these institutions in many ways including running Robotic Mining Competitions for several years. <https://www.nasa.gov/news-release/nasa-announces-robotic-mining-competition-2/>

<https://www.nasa.gov/learning-resources/stem-engagement-at-nasa/collegiate-miners-excavate-soil-for-nasas-robotic-mining-competition/>

Provide funding for USGS to partner with NASA on this and other academic projects and grants.

Additionally, it is important to not just spend the taxpayer’s money, but to create an environment that is conducive to public-private partnerships. Leveraging the private sector is America’s greatest strength and how we beat China, which is certainly funding their academics to devise ways to beat America to these resources.

There are billionaires, private equity firms, (friendly) sovereign wealth funds and many other investors eager to get in on the ground floor of America’s commercial space boom. Most of them are investing in rockets and satellites, but they understand the opportunity in lunar and asteroid resources. Providing small grants to *business schools* with space related programs so they may establish centers of excellence or startup incubators would help attract this private capital into the university ecosystem. These centers and incubators could connect investors with researchers and entrepreneurs.

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Dr. GOSAR. Thank you, Dr. Autry. I now recognize Dr. Milazzo for his 5 minutes.

**STATEMENT OF MOSES P. MILAZZO, OWNER OF OTHER ORB, CHIEF SCIENTIST FOR NASA’S PLANETARY DATA ECOSYSTEM, FLAGSTAFF, ARIZONA**

Dr. MILAZZO. Thank you, Chair Gosar, Ranking Member Stansbury, and members of the Subcommittee. My name is Dr. Moses Milazzo. I am the Founder and Owner of Other Orb LLC, a successful small business that provides planetary science consulting services to a variety of U.S. institutions, including private and public universities, for-profit and non-profit scientific organizations, and Federal agencies such as NASA.

I appear today on my own behalf, and not as a representative of any institution, agency, organization, or business. I thank you for the opportunity and honor to present testimony to this hearing. My goal through this testimony is to encourage you to proceed with careful consideration of the following aspects of any future space mining: resource and energy development, ethical consideration of public investment and returns, and ethical consideration of environmental and human burden that may be created by said mining.

The near-term enabling energy technologies for space-based mining will be solar panels and batteries. We have the opportunity, with the rapid growth of alternative energy sources and electric vehicles, to help develop more efficient and more resilient solar panels to support and tap into research and development of new, more robust and more energy-dense battery technologies, and to expand the testing environment of such batteries. Solar energy and EVs on our roads and highways represent the most advanced testing laboratory available for improving energy collection,

storage, and use, and the lessons learned can be applied to operations in space.

To guarantee that the public will benefit from an investment of public funds into space mining we need to ensure that public funding will be allocated in an equitable manner; anyone with the appropriate knowledge and skills will be able to compete for this funding; public funding will not only go to large and rich companies; public funding and the companies that receive this funding will be well regulated; that monopolies will not be permitted; that we will regulate the industry to ensure public good is achieved through public funding; and that this public funding does not create additional wealth disparities within our communities.

We also need to consider who will be responsible for the oversight of companies receiving Federal funding for space mining. We have historically failed to enact effective regulations during the earliest stages of a new industry. For example, during the industrial age disasters such as burning rivers were the result in part of an unregulated industry. We now have the opportunity to consider not only whether and how to fund this budding industry, but also how to ensure it protects and benefits the public that pays for it.

Space mining endeavors will have far-reaching impacts for humanity, and therefore anti-colonialism must be a central tenet of our regulation of the space mining industry. It is incumbent upon us, as we borrow from the future, to make decisions that benefit as much of humanity as possible, both today and far into the future. Just as various cultures hold certain geographical sites and features on Earth sacred, many cultures hold some planetary bodies sacred. We must seriously consider the harm that mining planetary bodies may cause to those cultures. Our concern for Apollo landing site preservation is no different from the concern others have for the preservation of whole planetary bodies in space.

A thorough and thoughtful plan for development of space mining must include codified protections and cooperative international agreements to preserve historical and cultural treasures. The question of whether and, if so, how to mine in space is one that needs careful consideration before a large expenditure of public funds is made. We stand in a singular position to do the right thing. We must use the lessons of history and advances in technology to not only help people on Earth in the near term, but to conserve our legacy for far-future generations.

Now is the time to bring in all stakeholders to discuss whether we should mine in space, how we might do so, and how doing so may benefit everyone rather than just a few people. The ideas and concerns I raise here are not exhaustive, but are intended as a framework for starting a deeper and more detailed dialogue.

To be clear, I am not opposed to mining in space. Personally, I think that there may be more positive outcomes than negative. But I am only one person. And as a scientist, I want my ideas, concerns, and excitement to be peer-reviewed by others with different perspectives. To that end, I urge the convening of a committee composed of historians, cultural experts, Indigenous representatives, ethicists, planetary scientists, lawyers, archeologists, anthropologists, industry experts, regulation and policy experts, and Federal

agencies to carefully consider the two main questions of whether and, if so, how to encourage, regulate, and fund U.S. mining in space. Thank you.

[The prepared statement of Dr. Milazzo follows:]

PREPARED STATEMENT OF DR. MOSES P. MILAZZO

Chair Gosar, Ranking Member Stansbury, and members of the Subcommittee, my name is Dr. Moses Milazzo. I am the founder and owner of Other Orb LLC, a successful small business that provides planetary science consulting services to a variety of US institutions, including private and public universities, for-profit and non-profit scientific organizations, and federal agencies such as NASA. I appear today on my own behalf and not as a representative of any institution, agency, business, or organization. Thank you for the opportunity and honor to present testimony to this Hearing on The Mineral Supply Chain and the New Space Race. My goal through this testimony is to encourage you to proceed with careful consideration of the following aspects of future space mining: resource and energy development, ethical consideration of public investment and returns, and ethical consideration of environmental and human burden that may be created by said mining.

I want to begin this testimony with a story about simple resource management in remote locations. I was born and raised on a small, self-subsistence ranch in the high desert of Northern Arizona. This ranch was far beyond the reach of grid-tied utilities: our water was supplied by a deep well into the Colorado Aquifer with a windmill-powered pump; we used wood-burning stoves for cooking and heating; and our only source of electricity were 12-volt car batteries used to power a radio and some small lights when our kerosene lanterns were out of fuel. One day in elementary school, I borrowed from the school library a book about a technology called photovoltaics. I asked my parents to get a solar panel for us to experiment with. We set up the solar panel to charge a 12-volt car battery and shortly afterward, we added a small black-and-white TV to our entertainment and news sources. The solar panel substantially decreased the cost of lighting and listening to music and the news on the radio and watching it on the TV; we no longer had to purchase kerosene or charge the battery with a gasoline generator. In this same book about photovoltaics, there was a section about the use of solar power on NASA's first space station, Skylab. It blew my mind that I, a poor kid on an off-grid ranch in the middle of nowhere, was now listening to the radio using the same power technology that NASA was using in space! My stepmom and two brothers still live on that ranch and still power the home with wind power, solar panels, and batteries.

**Executive Summary**

The question of whether and, if so, how to mine in space is one that needs careful consideration before a large expenditure of public funds is made. We stand in a singular position to do the right thing. We must use the lessons of history, and advances in technology, to not only help people on Earth in the near-term but conserve our legacy for far-future generations. Now is the time to bring in all stakeholders to discuss whether we should mine in space, how we might do so, and how doing so may benefit everyone rather than just a few people. The ideas and concerns I raise here are not exhaustive but are intended as a framework for starting a deeper and more detailed dialogue.

To be clear, I do not believe in stalling or blocking mining in space. Personally I think there may be more positive outcomes than negative. But I am only one person and as a scientist, I want my ideas, concerns, and excitement to be peer-reviewed by others with different perspectives. To that end, I urge the convening of a committee composed of historians, cultural experts, Indigenous representatives, ethicists, planetary scientists, lawyers, archeologists, anthropologists, industry experts, regulation and policy experts, and federal agencies (NASA, USGS, NSF, EPA, etc) to carefully consider the two main questions of *whether*, and if so, *how* to encourage, regulate, and fund U.S. mining in space.

**Energy and Resource Development**

The first and most significant factor in our ability to conduct space mining will be our ability to meet the vast energy requirements necessary. Mining requires very large energy expenditures here on Earth and will require even more in space. At this time, there's simply no known, better technology for humans taking advantage of the vast resources of solar energy than photovoltaics, the conversion of energy from the sun into electric power. Photovoltaics is a fundamental technology for

enabling space exploration because burning fuels is a particularly inefficient method for generating usable energy, and it is an especially expensive and inefficient method of generating energy for exploring space. On Earth, where we have abundant oxygen, we need only store and transport the fuel to be burned, be it kerosene for a lantern, gasoline for an internal combustion engine, or jet fuel for the airplane that brought me to Washington, DC. But in space, to take advantage of this kind of chemical energy, we would need to store and transport both the fuel and the oxidizer, which is prohibitively expensive and dangerous. We must therefore generate, store, transport, and provide that energy in some other form. While some of the energy will come in the form of nuclear energy, that source is already highly regulated, and I find it unlikely that our government or other governments will loosen those regulations. As such, the enabling technology for space exploration and commercialization of space is and will likely continue to be photovoltaics and batteries, which together allow us to generate, transport, and store energy in space without the massive inefficiencies of burning fuel.

Why does this matter? Because, to build a space mining industry, we will need very high capacity, resilient batteries that can withstand a variety of extreme environmental conditions and efficient and resilient photovoltaics to feed those batteries. We regularly see deliberate frustrations of developing photovoltaic and battery technologies through short-sighted anti-alternative energy initiatives, attempts to reduce funding for such technological advances, and anti-Electric Vehicle campaigns across the nation. If we are to seriously consider advancing our technology with the goal of acquiring essential minerals from space, we must rapidly and substantially advance our battery and photovoltaic technology. The most applicable, rapid-return development for this technology comes from alternative energy and battery research for the purposes of building electric vehicles of all sizes (including electric mining vehicles). EVs are the best approximation we have for testing and implementing new technologies that can be translated to space mining and material transportation.

#### **Ethical Public Investment**

If we commit to advancing these enabling technologies and to advancing the exploration of mining critical minerals in space, we must carefully consider how best to protect public investment and encourage a broad diversification of access to these technologies and to space.

As illustrated in recent news events, where a comment or tweet spurred a major telecommunications CEO to shut down satellite internet access to an entire nation, we should be careful of and wary of companies who claim to have the public good in mind. It is not within the strategic best interest of the United States to allow unregulated, large monopolistic companies to dominate resource extraction in space.

The mining industry is capital intensive, which means these businesses are more highly reliant on physical resources and capital (machinery and equipment) than on labor; labor only accounts for 7–8% of the cost of mining. The economics of space mining will be similar.

I know of no private companies that have sent any usable equipment out of Earth orbit and into space without some degree of public funding. Leaving Earth orbit is, like terrestrial mining, very capital intensive, but there's very little to no monetary return on investment in the short time periods traditionally expected by investors. This means that for the foreseeable future, few or no private companies will be leaving Earth orbit except with public funding, much less landing on or surveying asteroids or the Moon for resources. The nascent U.S. space mining industry will be dependent on U.S. federal funding so that the research, development, and capital costs can be afforded without the need to immediately meet investor expectations. There will be only minimal reduction in capital cost even after the research and development costs have been substantially reduced. For an extended period of time, it will be incredibly expensive to build space-capable machinery and to launch that machinery into space and it is unlikely that any space mining company will realize immediate profits.

Because of this likely need for public funding of research, development, and capital costs of the nascent space mining industry, it is incumbent upon all of us to carefully consider the following.

First, Federal funding for the space mining industry will pick winners and losers of this industry. Accordingly, we need to ask, will the public funding be allocated in an equitable manner? Will everyone with the appropriate knowledge be able to compete for this funding, or will it mostly go to already-large and rich companies? How will federal funding and the companies that receive this federal funding be regulated? What kinds of monopolies will we permit, and how will we regulate those monopolies to ensure public good is achieved through public funding? Will this

public funding create additional wealth disparities within our community? Should we use the taxes paid by a small business owner who farms buckeyes in Georgetown, OH, or a beef cattle rancher in Verde Valley, AZ, or a struggling household to benefit a large corporation that already has access to space?

In short: how will the public expenditures for space mining benefit everyone?

Second, we also need to consider who will be responsible for the oversight of companies receiving federal funding for space mining. We have historically failed to enact effective regulations during the earliest stages of a new industry—see the industrial age disasters such as the fires on the Cuyahoga River that were the result, in part, of an unregulated industry. We now have the opportunity to consider not only whether and how to fund this budding industry, but also how to ensure it protects and benefits the public that pays for it.

### **Environmental Considerations**

There are obvious environmental concerns to be addressed here on Earth arising from the likely exponential growth in mining for resources to produce many times more space-capable rockets and machinery than we currently produce. Space mining will incur environmental impacts here on Earth. Who will be expected to bear the fallout from those environmental impacts?

There are also, perhaps less obviously, environmental concerns for the mining of an asteroid in space. First, mining companies may need to park equipment in Low Earth Orbit (LEO) before sending it to the target asteroid when the orbital geometry is most favorable; they may choose to leave spent rocket boosters in LEO; or possibly allow the detritus to fall back to the Earth's surface. Each of these possibilities requires regulation and oversight. As evidenced by the Starlink satellite system, we know that a massive constellation of objects in Low Earth Orbit impacts our ability to scientifically survey the sky. This is significant not only for people who like to look at the night sky without light pollution or for scientists who study astrophysics and astronomy. An exponential increase in space junk in Low Earth Orbit would diminish the space mining industry's ability to detect both valuable resources and potential hazards. We are dependent on Earth-based instruments for gathering information about accessible asteroids. Without clear skies, we could lose not only the ability to visually enjoy our night skies and study our galaxy and the universe, but also the ability to effectively advise the very industry that is leaving behind this space junk.

We need to also consider the potential impact of hazardous debris being ejected from an asteroid during the mining process and colliding with Earth or affecting other space-based industries. Consider the possibility that after some years of mining on an asteroid that will pass near Earth, a mining company hasn't contained the unusable debris it generated. As that asteroid approaches Earth, we may no longer be able to use planetary defense technologies intended for large, mostly cohesive asteroid bodies and we will be poorly informed of the size and mass of debris that may threaten our atmosphere or surface, even if the main body of the asteroid does not. Similarly, mining an asteroid without careful consideration of how mining might impact the asteroid's solar orbit could potentially threaten the Earth by shifting the asteroid's orbit from a safe Earth flyby to a dangerous encounter. Unregulated mining on the Moon could cause debris to enter low lunar orbit and threaten historical artifacts such as the Apollo landing sites and impact other developing industries such as space tourism.

To avoid these nightmare scenarios, we need a well-considered plan for regulating mining activities on the moon or low-gravity bodies such as asteroids. NASA's DART mission produced data that may be helpful in creating a model for how much material might be disturbed from an asteroid's surface into its orbital path where it might 1 day cross Earth's orbital path.

As an avid outdoor enthusiast who frequents our nation's parks, monuments, and protected wild spaces, and who adheres to the "Leave No Trace" ethic, I also have recreation-related concerns about the environmental destruction that may occur in an unregulated space mining industry. Saturday afternoon before this hearing, I had the opportunity to spend some time visiting Muir Woods National Monument north of San Francisco, CA. During my walk through the Woods, I reflected on the fact that President Theodore Roosevelt created the Muir Woods National Monument in 1908, 115 years ago. I was quite thankful to both the donor of the land and to the President for having the foresight to preserve this unique natural, majestic space for future generations and this made me contemplate whether someone 115 years from today might be able to enjoy visiting heritage sites on, for example, the Moon or the asteroid Bennu. Anyone who has spent time in the wilds across much of America recognizes the beauty of living landscapes and we know from the majesty

of places like Death Valley that a landscape doesn't have to be filled with fauna and flora to be beautiful and important to humanity. Without a careful and deliberate approach to mining as an industry, future generations may not have the opportunity to explore that "Magnificent Desolation" Buzz Aldrin described during the Apollo 11 mission.

While we need to invest time and caution into any decision to implement space mining, we need to also consider the environmental-related ethical question of whether, in light of the significant environmental damage Earth-based mining causes, it would be ethical not to mine asteroids. Often, critical mineral extraction on Earth can involve mountaintop removal or open pit mining. Can we afford to continue this kind of mineral extraction here on Earth, our home and the only planet known to be capable of sustaining any kind of life? Because to our current knowledge no asteroids are capable of sustaining life, choosing to mine asteroids instead of Earth may be the more ethical consideration. We must apply further legal, ethical, scientific, cultural expertise to examining this question.

### **Cultural Considerations**

Because any space mining endeavors will have far reaching impacts for much of humanity, anti-colonialism must be a central tenet of our regulation of the space mining industry. It is incumbent upon us, as we borrow from the future, to make decisions that benefit as much of humanity as possible, both today and far into the future.

This includes considering the cultural impact of potential damage to historical and cultural sites. Do we want to preserve the sample selection site from OSIRIS-REx's Touch-And-Go (TAG) sampling of the asteroid Bennu? What about the golf balls Astronaut Alan Shepard hit while on the Moon? How should we approach the historical artifacts of our international partners and competitors? Will we allow mining on Comet 67P/Churyumov-Gerasimenko, which has the potential to cause damage to the European Space Agency's Philae lander? And, just as various cultures hold certain geographical sites and features on Earth sacred, many cultures hold some planetary bodies sacred. We must seriously consider the harm that mining planetary bodies may cause to those cultures. Our concern for the Apollo landing site preservation is no different from the concern others have for the preservation of whole planetary bodies in space.

Accordingly, a thorough and well thought-out plan for development of space mining must include codified protections and cooperative international agreements to preserve historical and cultural treasures.

### **Conclusion**

Space mining technology is not yet on our doorstep, but it is no longer science fiction. At this moment, we stand in a singular position to do the right thing. We must use the lessons of history and advances in technology, to not only help people on Earth in the near-term but conserve our legacy for far-future generations. Now is the time to bring in all stakeholders to discuss whether we should mine in space, how we might do so, and how doing so may benefit everyone rather than just a few people. The concerns I raise here are not exhaustive but are intended as a framework for starting a deeper and more detailed dialogue. I recommend the convening of a committee composed of historians, cultural experts, Indigenous representatives, ethicists, planetary scientists, lawyers, archeologists, anthropologists, industry experts, regulation and policy experts, and the several federal agencies (NASA, USGS, NSF, EPA, etc) to carefully consider the two main questions of *whether*, and if so, *how* to encourage, regulate, and fund U.S. mining in space.

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QUESTIONS SUBMITTED FOR THE RECORD TO DR. MOSES P. MILAZZO

**Questions Submitted by Representative Stansbury**

*Question 1. Does China have mining aspirations on the Moon?*

Answer. I believe so, but I am not a foreign policy expert. The stated goals of the Chinese National Space Administration include in-situ resource utilization (ISRU), which could be considered a precursor to mining. Several capabilities demonstrated by Chinese missions indicate they are hoping to establish a more permanent presence on the Moon. For example, the Chang’e 4 mission included plant seeds that were reported to have sprouted. Due to very low temperatures and a failure to keep the seeds warm, the experiment was terminated in 9 days instead of the planned 100. However, the experiment was successful in the sense that it demonstrated it is possible for seeds to sprout within a closed system on the Moon. On the other hand, this experiment may have been simple science similar to NASA and the US Forest Service’s collaboration to bring hundreds of tree seeds from five species to lunar orbit on Apollo 14 and return them back to Earth. Despite the seeds being exposed to vacuum, they were successfully germinated on Earth.

Despite such possible aspirations, the reality of space exploration and exploitation are very different and sending a pot of soil with seeds to space is a very early first-step. Remember, we have private companies that promised to land a rocket on Mars by 2016 (and 2018 and 2020 and . . .). Space exploration for science is very difficult,

but space exploration for resource extraction is exponentially more difficult and does not yet provide returns on investment. Many entities have aspirations of mining on the Moon or asteroids but the reality is that there are significant hurdles to achieving those goals.

*Question 2. How far along is China in advancing space mining?*

Answer. China is far from space mining. To date, China has returned a sample of the Moon back to Earth with its Chang'e 5 lunar sample-return mission in 2020. This sample had a mass of 1.7 kg. By comparison, the US has a total of 382 kg of lunar materials that were returned from the Moon with the Apollo missions; however, these samples would not be considered "mining." True mining requires significant and rarely-discussed technological advancements.

*Question 3. How accessible are critical minerals on the Moon?*

Answer. The talk of untold riches in space is similar to the story of El Dorado, the legendary and mythical city of gold that led many explorers astray. In one sense, critical minerals are all over the Moon—there are *small* amounts in nearly every scoop of lunar regolith (soil). However, these critical minerals are not realistically accessible and critical minerals that are most abundant on the Moon are already easily accessible on Earth. Specifically, minerals that are abundant on Earth, for example, plagioclase, pyroxene, olivine, and ilmenite, are also abundant on the Moon and on many asteroids. The metals associated with these minerals include Calcium, Aluminum, Silicon, Iron, and Magnesium. However, these are also highly abundant on Earth and the relative costs to acquire these minerals on Earth instead of in space are many orders of magnitude lower. Less common minerals and metals (such as Rare Earth Elements or REEs) are, in many cases, only available on the Moon and on asteroids in concentrations of parts per billion (ppb), meaning one would have to process a billion kilograms of material, at 100% efficiency, to obtain a single kg of pure mineral or metal.

Mineral maps of REEs on the Moon and asteroids may appear to show rich resources available at the surface, but this is only because the maps are intended to show differences in mineral concentrations; what appears to be a dramatic difference on the map may only be the difference between 2 ppb and 0.5 ppb. At this point in time it is not economically viable to process billions of kgs of material for the reward of only a few kg of minerals on the Earth, much less in space.

While we might consider infrastructure materials (steel, aluminum, etc) to be especially important to a space race that includes mining and other infrastructure developments; we need to also keep in mind other critical components of the infrastructure. For example, carbon is essential in producing steel from iron but is only seen in concentrations of less than about 100 ppb on the Moon. Carbon steel typically has a carbon content of 0.05% to 2.1% by weight. Accordingly, to make a metric tonne (1000 kg) of steel, we would need to gather between 0.5 and 21 kg of carbon. If one plans to mine all of their resources in space, that would require processing between 5 *million* and 210 *million* kg of material on the Moon to obtain the necessary 0.5 to 21 kg of carbon for producing 1 metric tonne of carbon steel. To develop a realistic mining infrastructure on the Moon, we might need several million metric tonnes of steel. In other words, we might need to process up to 100 trillion kg of material to build the infrastructure if we only use material acquired in space. A rough estimate for the average mass of near-Earth asteroids is around a trillion kg. While some of the near-Earth asteroids will probably have higher carbon concentrations than others, the reality is that a mining operation intending to acquire carbon and iron for creating infrastructure components might need to process an entire asteroid, or, more likely, several.

Carbon is just one of the many "minor" infrastructure components required to see realistic returns on mining in space that either needs to be acquired from somewhere in space or launched off the Earth. Neither option would be cheap or easy.

In addition, to acquire and process these millions to billions to trillions of kg of materials on the Moon, we would need very large transportation networks (many hundreds to thousands of km of trains, for example) to move these materials from their source to their refining centers, and those networks will depend on battery and solar power technologies as well as many materials acquired from the Earth and launched into space. If we were to build the networks for mining on asteroids and bringing materials back to Earth or to the Moon, we would also need a similar "train" of rockets to transport those materials.

The infrastructure requirements to expand humanity from Earth to anywhere beyond low Earth orbit are tremendous and incredibly complex, meaning any such effort will be expensive.

*Question 4. What are lunar “mascons”?*

Answer. Mascons are positive gravity anomalies relative to the mean shape of the body. For the Moon, this usually means there is a depression of some kind that has a higher gravitational pull than would be expected if mass were missing from this area. These are almost always in areas where there were large basaltic lava flows called “mare basalts”. These “mare basalts” are similar to Hawaiian basalts and consist mostly of pyroxene, plagioclase, and olivine, with minor amounts of other minerals. While there might be small amounts of critical minerals in some basaltic deposits on Earth or on the Moon, the concentrations are such that it’s simply not economically sensible to go after these sources of minerals because on Earth, hydrothermal systems have, over eons, concentrated these minerals for us for free. If these deposits had valuable concentrations of critical minerals, we would see terrestrial mining companies processing basaltic lava flows on Earth. Hydrothermal systems are not known to have occurred on the Moon or asteroids.

Related to mascons, there is a common misunderstanding regarding the formation of impact craters that an impacting object remains at the bottom of the resulting crater. However, most or all of the impacting object is vaporized and material is spread all around the impacted body, first as vapor that may be put into orbit (or may be pulled down to the surface of the body), which cools, condenses, and eventually joins the rest of the regolith on the surface. This wide dispersion of the vaporized material means that the concentrations of whatever material made up that impacting object are extremely low. This critical misunderstanding cost an Earth-based speculator in Arizona his entire fortune. Daniel Moreau Barringer staked a mining claim at what is now known as Meteor Crater in Northern Arizona, believing that a 50-meter diameter nickel-iron asteroid, with a mass estimated (by Barringer) to be 100 million tons (or worth around \$1B in 1903 dollars) had formed the crater and was buried beneath the surface. In actuality, the impactor had vaporized upon impact and had rained out over a wide area. Pieces of this meteoroid can still be found in the surrounding area. Barringer’s work to find this imagined fortune greatly improved our understanding of impact crater events, but it did nothing to make him rich.

*Question 5. What is Helium-3 (He-3)? What are its uses and how accessible is it on the Moon?*

Answer.

He-3 is an isotope of Helium that can theoretically be used as a relatively clean fuel for fusion. However, this is currently a science-fiction fantasy. We have no human-built operational fusion reactors other than nuclear bombs (which do not use He-3). The only other known, operating fusion reactor in our solar system is the Sun. Theoretically, fusion reactors may someday be usable, and our national laboratories may be on the verge of sustained nuclear fusion ignition in a laboratory setting. But, for nearly a century, we have speculated that we are “just” 30 years away from a solution for fusion power using known fusion fuels like deuterium (D) and tritium (T). We have never worked out a technological method for using He-3 in a fusion reactor because it is far more difficult than D-T or D-D reactions.<sup>1</sup>

Not only is the use of He-3 still far-future science fiction, its concentrations are, at best, only in the parts per billion on the lunar surface, so even if we could figure out how make He-3 fusion work, we would have to mine billions of kg of material to get a single kg of He-3. Moreover, containing and keeping He-3 pure and usable as a fuel is a non-trivial challenge.

He-3 is a potential clean fusion source for far-future use, but is not a practical goal in near-future commercial exploitation of space and is probably a direct road to bankruptcy because of the significant study still needed in physical laboratories before it could be ready for use in Earth reactors, much less space-based ones.

*Question 6. Some private companies are exploring methods for processing minerals in space. How close are we to successfully mining celestial objects and processing the resulting materials for use on Earth?*

Answer. We are in the early stages of forming theoretical methods for processing minerals in space but are still decades away from successful mining of celestial objects.

One company tried to put into practice a theoretical method that imitates gravitation separation for processing mineral ore in low earth orbit, but encountered multiple problems with its first experiment. Gravitational separation is the least energy intensive method we have for processing mineral ore on Earth and essentially uses

<sup>1</sup> <https://www.thespacereview.com/article/2834/1>

the fact that minerals all have different densities to separate them from each other. On Earth, we can shake, agitate, or otherwise disturb a mixture of useful minerals and less useful materials to separate them according to their densities. A good example is panning for gold: we put some soil that might contain gold into a pan of water and agitate it for a bit. The water allows the less dense materials to float when agitated while the more dense gold sinks. We remove those less dense materials and are left with a more gold-rich soil. We can repeat the process to further concentrate the gold in the soil. This process is similar to the industrial processes used to separate large volumes and masses of minerals from their ores.

There are several theoretical ways to imitate gravitational separation for mineral processing in space, one of which is to use magnetic fields to create the separation. This method uses the magnetic properties of minerals rather than their densities to create separation and is the method the space mining startup attempted. However, testing the theory became impossible because of numerous spacecraft issues directly conflicted with testing requirements. Specifically, large magnetic fields generated on low-earth orbiting spacecraft interfere with the spacecrafts' attitude and control systems and cause the spacecraft to tumble out of control. The strength of the gravitational field required for differential mineral processing is so large that it would be nearly impossible to cheaply shield the spacecraft's attitude control system from that magnetic field. The energy costs to scale this magnetic field to process more than a few grams at a time become astronomical.

Outside of Earth's orbit, gravitational separation could be simulated in spacecraft under constant rocket acceleration that generate the needed simulated gravity, but this is incredibly expensive and would require a long time and a corresponding amount of fuel for the separation to occur.

A centrifuge could be used to simulate gravity but again, for large masses (in most cases billions of kg of material processed to obtain a single kg of usable mineral), this becomes extremely expensive. We might try to do this on the Moon, but the lunar gravitational field is one sixth the strength of Earth's, so the time needed for processing would be greatly increased and would require greater energy expenditures. And, as noted previously, all of this is theoretical and untested in any capacity.

*Question 7. How could the circular economy on Earth be useful for acquiring critical minerals?*

Answer. Earth currently produces about 50 million tons of electronic waste every year. In addition, we also generate huge amounts of unmonitored non-electronics waste that contains critical minerals and metals. Our landfills are overflowing with decades' worth of electronic and electrical waste that hold critical metals and minerals in concentrations thousands of times greater than our most productive mines. There currently exists a secondary market of individuals who buy old CPUs on popular auction websites to process and collect the gold from those CPUs; even at very small scales, this is lucrative. At scale, processing landfill and recycled materials for critical minerals is probably the most lucrative approach to filling the gap in our critical minerals needs; companies looking to seriously produce low-cost precious metals and critical minerals would be wise to start with landfills.

*Question 8. Should the United States be concerned about its future access to space, the Moon, or the rest of the Solar System considering claims that foreign adversaries are investing in settlements and mining projects in space?*

Answer. I don't believe so. Our access to space is limited only by our ability access near-Earth airspace; once a rocket moves away from Earth and into space, its access to the Moon, asteroids, and the rest of space increases with its distance from Earth. If a foreign adversary wanted to threaten our access to space, it would have to do so as near to the Earth's surface as possible, which raises a far different issue. Once an entity begins operations in space, the danger posed by any kind of adversary significantly diminishes.

While international space agreements could be improved and updated, the reality is that once an entity has established a safe way into space, its access to space is unlikely to be threatened by the presence of another entity.

That's not to say foreign adversaries building access to space is without potential danger. Most significantly, there are cultural treasures in space, both human-made and natural, that may be threatened by entities disregarding existing or future international agreements. I believe a diplomatic approach, both within the United States and internationally, is most likely to result in successful protection of cultural artifacts, environmental conditions, human rights and lives, and technological advancement.

The most consequential limitation on our ability to access space will not come from foreign adversaries, but from our own willingness to fund education and the necessary research for advancement in energy resources. We are woefully behind other nations on crucial technologies such as large capacity battery storage and solar power generation and are expending pointless time and energy fighting ourselves over those technologies and the ones they will need to replace (fossil fuels will be useless in space). We have lost the edge on education; our national fear of innovations in science, mathematics, and humanities education has put us decades or more behind the technological advancements of other countries. We fight our own workers and labor unions instead of incentivizing them to be innovative and productive. If we want to lead in space, we must return to our position as a global leader in education, workers' rights, and human rights in general.

*Question 9. Besides on Earth, is there currently any permanent human presence in the solar system?*

Answer. No. The closest anyone has to a permanent human presence in the solar system is the International Space Station. We have robotic space missions exploring the solar system, but the farthest humans have gone outside of low Earth orbit is to the Moon. Eugene Cernan commanded Apollo 17 (11 to 14 December, 1972) and was the last person to walk on the Moon. The crew of Apollo 17 were the last humans to travel outside of Earth's orbit.

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Dr. GOSAR. Thank you, Dr. Milazzo. I now recognize Ms. Hanlon for her 5 minutes.

**STATEMENT OF MICHELLE HANLON, EXECUTIVE DIRECTOR,  
CENTER FOR AIR AND SPACE LAW, THE UNIVERSITY OF  
MISSISSIPPI SCHOOL OF LAW, UNIVERSITY, MISSISSIPPI**

Ms. HANLON. Chairman, Ranking Member, and members of the Subcommittee, I thank you for convening this hearing which recognizes the ability to access and utilize extraterrestrial natural resources must be considered as the United States looks to the future of the mineral supply chain, and I thank you for your invitation to testify.

My name is Michelle Hanlon. I am a space lawyer. I am the Executive Director of the Center for Air and Space Law at the University of Mississippi. I am the Co-Founder and President of For All Moonkind, which is the only organization in the world focused on protecting human heritage in outer space, like the Apollo and lunar landing sites. And finally, I am also the Founder and Executive Director of the Institute on Space Law and Ethics.

I am heartened to see growing recognition of both the promise of space resources and the fact that we find ourselves once again in a space race. Only this time the stakes are much higher than before. This race is not about prestige. It is about access to resources that can benefit the lives of all Americans, all humanity. And it is about the governance framework that will support the management of these resources and all future space activities.

Earth occupies a very small part of space. Around us are an infinite source of resources. How we characterize the extraterrestrial domain is important. The United States considers space to be a unique domain of human activity, not a global commons. This description of the cosmos allows for responsible stewardship while leaving open possibilities we have not yet had the opportunity to contemplate. Indeed, we may one day agree that the broad expanse of space is susceptible to not one, but several categorizations. It is important, vital that we use our terrestrial

experience to inform, not constrain, our view of the universe and the management and use of its resources.

Space is not a global commons, but nor is it a lawless wonderland. However, the international regime governing extraterrestrial activities was not designed for space resource utilization. The treaty instruments were developed under the guidance of President Eisenhower, with the primary goal of keeping outer space for peaceful purposes. The Outer Space Treaty has been largely successful in this regard, but it leaves much susceptible to interpretation in other regards, a dangerous circumstance.

For example, the Outer Space Treaty states that space shall be free for exploration and use by all, which implies that resource extraction is permissible, an interpretation President Obama endorsed as U.S. law in 2015, and which is also enshrined in the multilateral Artemis Accords. But the treaty also states that a nation may not claim territory in space by any means. Occupying a mineral-rich area of an asteroid could be considered a territorial claim.

Article IX of the Outer Space Treaty requires that parties act in space with due regard to the activities of others. Thus, under the Outer Space Treaty, simply maintaining a presence in one specific area of a celestial body might violate the non-appropriation principle. However, the concept of due regard suggests that if one entity is already occupying, others must avoid interfering. This gives a tremendous advantage to those who simply establish a presence first. So, the race begins.

The Artemis Accords proposed that “due regard” requires others to respect reasonable safety zones around activities. But what is reasonable? Without a more specific construct of due regard, the entity that gets to a desirable area first can easily make the argument that due regard reasonably requires other parties to maintain a distance measured in kilometers in order to assure the protection of their operations.

What is worse, these rules could by default apply not just to one particular celestial body, but can become the foundation for all extraterrestrial resource management, wherever the source.

Currently, the United States’ closest competitor in this new space race is China. China has made no secret of its own space resource utilization plans. And remember, winning requires only getting there first. Once a spacecraft of any kind lands or even crashes in a mineral-rich area, due regard, it could be asserted, requires that no other entity approach within 20 or more kilometers of that certain spacecraft, thereby creating a safety zone that effectively excludes access by others to any minerals found in that area.

We must accelerate our efforts to assure continued access to extraterrestrial resources. This hearing is a first but significant small step. U.S. policy as a whole, and not just space policy, must acknowledge and embrace the vast resources the universe offers. The United States must encourage and increase support for commercial mining activities. The United States must also continue to encourage the growth of the Artemis Accords and work within the Accords and the United Nations Committee on the Peaceful Uses of Outer Space to better define due regard. Thank you.

[The prepared statement of Ms. Hanlon follows:]

PREPARED STATEMENT OF MICHELLE L.D. HANLON, EXECUTIVE DIRECTOR,  
 CENTER FOR AIR AND SPACE LAW, UNIVERSITY OF MISSISSIPPI  
 AND PRESIDENT AND CEO, FOR ALL MOONKIND

**I. Introduction—It is a Race**

Chairman Gosar, Ranking Member Stansbury and Members of the Subcommittee, my name is Michelle Hanlon. I am a space lawyer and the executive Director of the Center for Air and Space Law at the University of Mississippi. We are the only ABA accredited law school in the country to offer a Juris Doctorate degree with a concentration—as well as an advanced master of laws—in air and space law. The University of Mississippi possesses a deep tradition of research, analysis, education and advancement in space law going back to the 1960s when the first international treaties governing space activities were being negotiated. I am also the co-founder, President and CEO of For All Moonkind, a nonprofit that is the only organization in the world focused on protecting human cultural heritage in space, like the Apollo lunar landing sites. We are a Permanent Observer to the United Nations Committee on the Peaceful Uses of Outer Space, a position which affords a view into international deliberations regarding space activities.

Finally, I am the founder of the Institute on Space Law and Ethics, an organization that brings together diverse perspectives on space exploration. Our mission is to ensure that ethical considerations continuously serve a foundational role in shaping the legal and normative frameworks governing the exploration and use of outer space, with the goal of enhancing mutual understanding, transparency, trust and the sustainable use of space and its resources for the benefit of all humankind while minimizing misunderstandings and the potential for conflict.

I am grateful for the opportunity to testify today in respect of the Mineral Supply Chain and the New Space Race. It is without question that the decisions made today with respect to the exploration and use of space and its resources will have far-reaching implications for future generations, and indeed, all humanity, whether in communities here on Earth or elsewhere in the cosmos. Some regard space and its resources as a savior of our Earth, able to provide energy and other resources as our terrestrial supplies dwindle. Others will tell you that space exploration is a wasted investment. But what is inarguable is that humanity has greatly benefited from the use of assets in space. It is also incontrovertible that the future sees only more dependence on space assets and resources. We do not—we cannot—know what solutions space may hold, and we will not unless we continue to explore and expand into the upper reaches of space.

For these reasons, I am heartened to see growing recognition of both the promise of space resources and the fact that we find ourselves, once again, in a space race. Only this time, the stakes are much higher than before. This race is not about prestige, it's about access to resources that can benefit the lives of all Americans—all humanity—and it's about the governance framework that will support the management of these resources and all future space activities. Contrary to popular belief, space is not a lawless wonderland. There are four widely-ratified international treaties that govern space activities. Negotiated in the 1960s and 70s, they provide a solid baseline. Nevertheless, they are broadly worded, suffer from internal inconsistencies and glaring gaps and are subject to varied interpretations. Chief among the grey areas are questions related to the ownership and use of extraterrestrial resources. For example, while binding international law states that the exploration and use of outer space shall be free for exploration and use by all, which implies that resource extraction is permissible, it also states that a nation may not claim territory in space, which calls into question how a space resource mining operation would be able to protect its investment. Given these and other grey areas, there exists a potentially serious first mover advantage which the United States must understand and take into consideration as it implements space and natural resource policies and competes in this new space race.

**II. The Outer Space Treaty Regime Was Not Designed for Space Mining**

*A. President Eisenhower Initiated Negotiations to Keep Space Peaceful*

In October 1957, Sputnik 1 became the first human-made object to reach space. Shortly thereafter, President Eisenhower initiated negotiations to secure space for peaceful purposes. His efforts ultimately led to the development by the United Nations (UN) of an ad hoc committee, the Committee on the Peaceful Uses of Outer Space (COPUOS), which was made a permanent UN body in 1959. The COPUOS

above all recognizes “the common interest of [hu]mankind in outer space” and “the common aim that outer space should be used for peaceful purposes.”<sup>1</sup>

COPUOS was the backdrop for the negotiation and implementation the treaties which today govern space activities. The first, the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (the Outer Space Treaty), was ratified in 1967. This Treaty, with 114 signatories including the United States (US), Russia, China and most every spacefaring nation, enshrines the fundamental concept that outer space “shall be free for exploration and use by all.” Essentially a demilitarization instrument, the Treaty does not contemplate the management and use of extra-terrestrial natural resources. In fact, it does not once mention the word resource. However, it does impose limitations on the freedom of exploration and use. First, is the non-appropriation principle, which stipulates that no country may claim territory in space. And second, the Treaty requires that all activities in space be conducted with due regard for the corresponding interests of others.

Four other treaties related to sovereign space activities were negotiated in the wake of the Outer Space Treaty. These are colloquially known as the Rescue Agreement, the Liability Convention, the Registration Convention and the Moon Agreement. As their names suggest, these agreements respectively offer more detailed guidance on how countries should act in relation to the rescue of astronauts; responsibility and liability for damage caused by space objects; and the registration of objects launched or intended to be launched into orbit. The Moon Agreement was the international community’s first attempt to regulate the access to and management and utilization of extraterrestrial natural resources. It has been ratified by only 18 States. The United States, China and Russia are not parties to that Agreement and Saudi Arabia is withdrawing from the treaty in January 2024.

The bottom line is that there are gaps in the law which may be filled by the first mover.

#### *B. Space Cannot Be a “Global Commons”*

Earth occupies a very small part of space. Around us are an infinite source of resources. How we characterize the extraterrestrial domain is important. Many say that space is a global commons. The UN defines the term “global commons” as “those resource domains that do not fall within the jurisdiction of any one particular country, and to which all nations have access.”<sup>2</sup> Global commons require global governance, a notion that has been executed well in only rare circumstances. The UN identifies four “global commons:” the high seas, the atmosphere, Antarctica and outer space.

This notion that space is a global commons must be challenged. First, the Outer Space Treaty does not identify outer space as a global commons. Second, the very term “global” suggests that global commons must be bound, in some way, to Earth. Things that happen in the high seas, the atmosphere or even Antarctica could have direct impact on the health and welfare of countries, communities and individuals around the world. These areas also play an integral role in the health of our global ecosystem and environment. If someone, entity, or country operates a mine on a random asteroid in the Kuiper Belt, while the ultimate impact will benefit human society by providing a new supply of resources, it surely will not have a direct impact on the health and welfare of Earth communities or the Earth’s ecosystem (except, again, perhaps as a benefit by moving heavy industry off-Earth).

Finally, the concept that the vast infinity of space is a human resource domain is the utmost of anthropocentric hubris. Are we truly asserting that all of space is the sole responsibility and domain of Earthlings alone?

Despite the UN stance, the United States has never, as a matter of international policy, considered space to be a global commons. A 2020 Executive Order issued by President Trump formalized this position and characterized space, instead, as a unique domain of human activity. This, is a far more flexible description of the cosmos as it allows for responsible stewardship while leaving open possibilities we have not yet had the opportunity to contemplate. Indeed, we may one day agree that the broad expanse of space is susceptible to not one, but several different categorizations. We must use our terrestrial experience to inform, not constrain, our view of the universe and the management and use of the resources it holds.

It is notable too that recently proposed legislation, the Commercial Space Act of 2023, also includes a provision stating that “outer space may not be considered a global commons.”

<sup>1</sup> U.N.G.A. Res. 1472 (XIV) (Dec. 12, 1959).

<sup>2</sup> United Nations System Task Force on the Post-2015 UN Development Agenda.

That said, the United States is bound by the Outer Space Treaty which does place limits on space activities.

*C. The Exploration and Use of Space is the Province of All Humankind*

Article I of the Outer Space Treaty describes the exploration and use of space as “the province of all [hu]mankind.” This is markedly different from term used in Article 11 of the Moon Agreement which characterizes the Moon and its natural resources as “the common heritage of [hu]mankind.” It is an important distinction.

Ambassador Arvid Pardo of Malta is credited with introducing the principle of “common heritage of humankind” as a system of resource management in 1967 during the negotiation of the Law of the Sea Treaty.<sup>3</sup> The concept of was more fully developed by the United Nations in a 1970 resolution which declares “the sea-bed and ocean floor, and the subsoil thereof, beyond the limits of national jurisdiction, as well as the resources of the area, are the common heritage of [hu]mankind.” This means, the resolution goes on to note, that these areas and resources “shall not be subject to appropriation by any means by States or persons, natural or juridical.”<sup>4</sup>

The concept of “common heritage” as encapsulated in the Moon Agreement suggests that: 1) no State or private entity may claim or use resources until and unless authorized and approved by a, presumably, United Nations-driven common management; and 2) any benefits which accrue as a result of any exploitation or use must be equitably shared.

It is deeply significant that the Outer Space Treaty does not adopt this nomenclature, suggesting that outer space and its resources shall be considered and utilized in a manner different from that which governs “common heritage” as described in the Moon Agreement or the Law of the Sea.

Regardless of what is meant by the term “province of all [hu]mankind,” the concept of freedom of exploration and use of space is the guiding force governing space activities. This is further buttressed by the additional agreement in the Outer Space Treaty that “there shall be free access to all areas of celestial bodies.” These freedoms to explore, use and access are barely curtailed by the other provisions of the Treaty. The only restrictions imposed on these freedoms are that:

- Exploration and use shall be carried out for the benefit and in the interests of all countries (Article I)
- States may not claim territory in space (Article II).
- International law applies in space (Article III).
- Nuclear weapons or any other kinds of weapons of mass destruction may not be placed in orbit or on any celestial bodies (Article IV).
- The Moon and other celestial bodies shall be used exclusively for peaceful purposes (Article IV).
- All activities in outer space must be conducted with “due regard” for the corresponding interests of others (Article IX).

The benefits, non-appropriation and due regard principles, have the most bearing on the extraction and use of extraterrestrial mineral and other resources.

For clarity’s sake, it is important to note here that the Treaty does reach private, non-State activity. Article VI obligates countries to assure that all “national activities are carried out in conformity with” the Treaty. The Article also makes it quite clear that countries bear “international responsibility for national activities in outer space . . . whether such activities are carried on by governmental agencies or by non-governmental entities.” In space, essentially, everything that is done even by a nongovernmental entity is considered to be done by the State even if it otherwise had no involvement in the mission or activity.<sup>5</sup>

<sup>3</sup>Statement of Mr. Pardo, 22nd Session of the United Nations General Assembly, U.N. Doc. A/C.1/PV.1515, 1516 (Nov. 1, 1967) (It would “be wise to establish some form of international jurisdiction and control over the sea-bed and ocean floor underlying the seas beyond the limits of present national jurisdiction.”).

<sup>4</sup>U.N.G.A. Res. 2749 (XXV), § 1 (Dec. 16, 1970).

<sup>5</sup>To demonstrate how Article VI might affect space mining activities, we turn to events that occurred in Low Earth Orbit in 2021. On December 3, 2021, the Chinese government used a diplomatic message known as a Note Verbale to complain that small satellites owned and operated by SpaceX had forced them to implement “preventive collision avoidance” measures to protect their space station on two separate occasions. Helpfully, the Chinese government also took the opportunity to remind all countries of their Article VI responsibilities. The message was clear. US, you have created a space hazard by not properly supervising your non-governmental entity and if something happens to our space station or our astronauts, you will be liable. In

#### D. Space Mining Benefits All

Returning to the restrictions on freedom of exploration and access, Article I is clear that any exploration and use shall be carried out for the benefit and in the interests of all countries. Some would argue that the concept of shared benefits means sharing monetary profits. This is a very narrow view of the word “benefit.” The phrase also offers no indication of when a benefit must accrue. Removing immediacy, there is no doubt that every single country on Earth has benefited in some way from space activities, be it from remote sensing satellites that share weather predictions and climate information to GPS and telecommunications.

Space mining will also provide benefits to all countries, indeed all humanity on multiple levels. First, as we have seen so often with space activity, the tools developed to implement off-Earth mining operations require technological advancement that will enhance the human experience on Earth in ways we cannot even begin to imagine. Mining for water in particular, may provide direct benefits to areas here on Earth where water is a scarce resource. Second, mining will also increase our scientific knowledge of the universe around us. Understanding the composition of our celestial neighbors will provide much insight which can ultimately help us better care for our Earth. Third, extracting and using off-Earth resources will make it more efficient for us to explore further into the reaches of the Universe, again compounding our potential scientific discovery. Finally, discovering and mining resources on other celestial bodies will relieve the pressure on our own and help us protect and even heal our terrestrial environment and end our reliance on children and other laborers earning less than \$2 a day mining for cobalt in places like the Congo.<sup>6</sup>

In the short term, it may appear that only a select few entities—whether national or private—have the capability to even consider commencing mining operations in space. There was a time that only a select few entities had the capability to sustain a national or private airline, and yet today the air industry is the backbone of our global economy. That said, care must be taken to assure that benefits are accessible to all, including future generations which implies that while the multiple benefits described above create an ethical imperative to develop extraterrestrial mining operations, there is an equal imperative to do so responsibly.

### III. Opportunity for Interpretation Creates a First Mover Advantage

#### A. The Non-appropriation Principle: So Much Left Open

Article II of the Outer Space Treaty states in full: “Outer space, including the Moon and other celestial bodies is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.”

##### 1. National Appropriation Does Not Apply to Extraction

Article II could have been interpreted to apply both to territory in space and the resources in that territory. However, reference must be made once more to the Moon Agreement which clearly states in Article 11(3) that “[n]either the surface nor the subsurface of the moon, *nor any part thereof or natural resources in place*, shall become property of any State, international intergovernmental or non-governmental organization, national organization or non-governmental entity or of any natural person.”

Once again, it is deeply significant that the Outer Space Treaty does not include this language, suggesting that Article II does not apply to parts of celestial bodies or the resources contained therein.

As far as resources contained in celestial bodies, it is also worth noting that each of the US, China, Russia and Japan have obtained material directly from the Moon or other celestial body for use—albeit scientific rather than commercial—without objection by any other country. This supports the interpretation that the non-appropriation principle does not apply once a resource is extracted from its source.

The US interprets Article II in this way. The Commercial Space Launch Competitiveness Act,<sup>7</sup> signed into law by President Obama in 2015, recognizes

its response, the US chided the Chinese government for not reaching out bilaterally, however, it also implicitly recognized US responsibility for the privately-owned and operated SpaceX spacecraft even though it was not undertaking any tasks at the behest of the US government. If a private entity causes damage in space, the State in which the entity was formed, or in which it may be considered a national, will be liable regardless of the level of due diligence it may have exercised in respect of the activity.

<sup>6</sup><https://www.npr.org/sections/goatsandsoda/2023/02/01/1152893248/red-cobalt-congo-drc-mining-siddharth-kara>

<sup>7</sup>U.S. Commercial Space Launch Competitiveness Act, H.R. 2262, 114th Cong. (2015).

commercial property rights in resources extracted from celestial bodies stating unequivocally that:

A United States citizen engaged in commercial recovery of an asteroid resource or a space resource under this chapter shall be entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell the asteroid resource or space resource obtained in accordance with applicable law, including the international obligations of the United States.

President Trump reaffirmed this in his 2020 Executive Order which, among other things, proclaims that “American should have the right to engage in commercial exploration, recovery, and use of resources in outer space,” and urges executive departments to “take all appropriate actions to encourage international support for the public and private recovery and use of resources in outer space.” Luxembourg, United Arab Emirates and Japan have similar legislation and India has recently released a space policy that also supports this interpretation.

It is also captured in the Principles for Cooperation in the Civil Exploration and Use of the Moon, Mars, Comets, and Asteroids, known colloquially as the Artemis Accords.<sup>8</sup> Although these Accords are not a binding instrument, the Accords have been agreed by 33 nations (as of December 8, 2023). Included in the Accords is the affirmation “that the extraction of space resources does not inherently constitute a national appropriation under Article II of the Outer Space Treaty . . .” Neither China nor Russia has signed the Artemis Accords.

## 2. What About Parts of the Moon?

The language of Article II of the Outer Space Treaty can be interpreted to mean that no nation may claim *the whole* of outer space, the Moon or any other celestial body as territory. Arguably, then, it is silent as to *parts*. Does this mean a nation can claim a part of the Moon, or a part of an asteroid so long as it does not claim the whole? Arguments can be made for this interpretation.

## 3. If You Mine it, You Own it, But Can You Protect it?

Interpreting Article II to permit space resource extraction is just a first step. How can any country or private party establish a resource extraction operation if territory cannot be claimed?

Clearly, if a country is simply occupying or using an area in space, it cannot be considered that country’s territory, but what rights does it, or a private entity acting in conformity with the Outer Space Treaty have with respect to that occupancy? And what is meant by the concept of “by any other means?” These provisions conflict with other parts of the Outer Space Treaty. Pursuant to Article VIII, objects left in space remain under the ownership and control of the State that put them there. In fact, pursuant to Article VII of the Outer Space Treaty and Article III of the Liability Convention, States are “internationally liable” for damage caused to an object in space belonging to another State. So, you cannot cause damage to someone else’s object without incurring liability. Yet leaving the objects *in situ*, or forcing others to give them wide berth in order to avoid liability, essentially results in perpetual occupation of the surface upon which they rest. And perpetual occupation feels like appropriation and a violation of the free access principal.

Interestingly, Article XII of the Outer Space Treaty does contemplate the installation of facilities on the Moon and other celestial bodies. Any such facilities shall be open to all, on the basis of reciprocity and after appropriate consultation. It is not difficult to anticipate that this provision may be easily abused.

## 4. Claim of Sovereignty Prohibited—But What if Not a Sovereign?

Should we treat private entities differently? The international community seems largely to agree that no nation may make a claim to extraterrestrial territory. Nevertheless, a colorable argument can be made that this particular provision does not apply to non-State entities. First, the Article plainly indicates that space shall not be subject to *national* appropriation. Second, the primary restriction is against appropriation by claiming *sovereignty*. Arguably, then, if a non-State entity asserts proprietary rights, it is not a “national appropriation,” nor is it “by claim of sovereignty.” This interpretation is supported by the United Nations Declaration of Human Rights, which, in Article 17 plainly states that “[e]veryone has the right to

<sup>8</sup>The Artemis Accords, NASA, <https://www.nasa.gov/specials/artemis-accords/img/Artemis-Accords-signed-13Oct2020.pdf> (last visited Apr. 17, 2022).

own property alone as well as in association with others.”<sup>9</sup> The Declaration applies to space activities through Article III of the Outer Space Treaty which requires States to “carry on activities in . . . space in accordance with international law.” Surely, this would require States to support and defend fundamental human rights even in a space environment. As such, arguably, it would be a violation of international law to not permit ownership in space.

As Stephen Gorove, the founder of our air and space law program at the University of Mississippi put it back in 1968: “an individual acting on his [or her] own behalf or on behalf of another individual or a private association or an international organization could lawfully appropriate any part of outer space, including the moon and other celestial bodies.”<sup>10</sup> Though this position has not been formally advanced by any nation, the concept of sovereign versus non-sovereign appropriation bears further consideration. While in the short term it seems a dependable barrier to territorial claims by adversary countries, it also may preclude the ability to protect or decline access to sites that require protection whether due to the presence of sensitive instruments or cultural artifacts.

*B. Due Regard—A Definition TBD by the First Mover*

Also layered on top of the non-appropriation principle of Article II are the requirements, contained in Article IX of the Outer Space Treaty that, among other things: 1) all activities in outer space be conducted with “due regard” to the corresponding interests of other States; and 2) if one country “has reason to believe” that its activity will cause “potentially harmful interference” to another, it must “undertake appropriate international consultations.” To be clear, harmful interference is not prohibited—it must simply be accompanied by a warning to the party which may be harmed. In short, this provision has no teeth and can be considered little more than a notice requirement.

Both the concept of due regard and the admonition to warn of harmful interference suggest that States should not interfere with or otherwise despoil the objects of another and clearly conflicts with freedom of access enshrined in Article I of the Treaty and the “by any other means” provision of Article II. Plainly, a balance must be struck between access, appropriation and “due regard.” But “due regard” is a standard that remains undefined. An international arbitral tribunal considered the meaning of “due regard” in 2015 and determined that “due regard” requires a balancing test, taking into consideration the rights of the State that have been impinged by the contested activity, the extent of the impairment, the nature and importance of the contested activity, and the availability of alternative approaches. This balance will produce different outcomes on a case-by-case basis, an uncertainty which in and of itself is enough to make States and their nationals consider carefully their international obligations in respect of extraterrestrial mining activities.

Thus, under the Outer Space Treaty, simply maintaining a presence in one specific area of a celestial body, be it the Moon or an asteroid, triggers the non-appropriation principle. However, the concept of due regard suggests that if one entity is already occupying and using a specific area, others must avoid interfering. This gives an advantage to those who establish a presence first. And so the race begins. Without a more specific construct of “due regard,” the entity that gets to a desirable area first can easily make the argument that “due regard” requires other parties maintain a distance measured in kilometers in order to assure the protection of their object or objects. What’s worse, these rules, could by default apply not just to one particular celestial body, but can become the foundation for all extraterrestrial resource management, wherever the source.

In 2011, NASA issued voluntary guidelines<sup>11</sup> intended to protect the instruments left at Apollo and certain US robotic landing sites. These guidelines established exclusion zones that were set arbitrarily by scientists and engineers who made assumptions about potential damage from the lunar regolith ejecta which is known to be particularly abrasive. In 2020, President Trump signed the One Small Step Act which made these guidelines binding on any entity in a contractual relationship with NASA. They do not bind any other countries or entities.

The Artemis Accords, which were developed in part to fill gaps in international space law, also seek to establish guidelines to satisfy the concept of due regard. In a section entitled “Deconfliction of Space Activities,” the Accords require signatories

<sup>9</sup>U.N. Declaration of Human Rights, art. 17, <https://www.un.org/en/about-us/universal-declaration-of-human-rights>.

<sup>10</sup>Stephen Gorove, *Interpreting Article II of the Outer Space Treaty*, 37 Fordham L. Rev. 349, 352 (1969).

<sup>11</sup>[https://www.nasa.gov/wp-content/uploads/2017/10/617743main\\_nasa-usg\\_lunar\\_historic\\_sites\\_reva-508.pdf](https://www.nasa.gov/wp-content/uploads/2017/10/617743main_nasa-usg_lunar_historic_sites_reva-508.pdf)

to “respect the principle of due regard” and “refrain from any intentional actions that may create harmful interference.” The signatories to the Accords further commit to “provide notification of their activities and commit to coordinating with any relevant actor to avoid harmful interference. The area wherein this notification and coordination will be implemented to avoid harmful interference is referred to as a ‘safety zone’ . . .” Finally, the Signatories agree to “respect reasonable safety zones to avoid harmful interference with operations under [the] Accords, including by providing prior notification to and coordinating with each other before conducting operations” in the safety zone of another Signatory.

This safety zone construct is essentially a proposal to bring certitude to the balancing test of Article IX’s due regard. However, the language states that the signatories will “respect reasonable safety zones.” The concept of reasonableness will necessarily be determined by the party that was their first. As noted above, neither China nor Russia has acceded to the Artemis Accords. In fact, they have collaborated on their own lunar project, the International Lunar Research Station (ILRS), which, as of December 8, 2023, has eight countries formally involved. Unlike the Artemis Accords, the ILRS is focused on scientific and engineering collaboration and thus do not, as yet anyway, incorporate any policy or legal principles with respect to appropriation or due regard. However, the Accords offer non-signatory countries the opportunity to take advantage of the publicly distributed language. Should China land on the lunar South Pole and claim a “reasonable” zone of a 20-kilometer diameter, how can Artemis signatories complain?

#### **IV. The Potential for the First Mover to Exploit “Due Regard”**

The Outer Space Treaty has no enforcement mechanism. Disputes are intended to be settled through diplomatic channels. Barring that, claims may be brought to the International Court of Justice. There is no definition of “due regard” and thus the outcome of claims will be uncertain. Indeed, the broad language of and gaps in current international space law can be exploited to rationalize activities and claims others would consider unreasonable or in violation of the law. Moreover, international laws and norms are easily ignored and even flouted without consequence on Earth. There is no reason to believe that this will change when implementing activities beyond Earth.

Make no mistake. Right now, we are in race. Even if interested parties were inclined to enter into negotiations to establish a treaty on extraterrestrial resource management and utilization, treaties take a long time to develop. In the meantime, legal norms will be established by activity, and the first actors will establish those norms.

Some have speculated that the Chinese government will withdraw from the Outer Space Treaty when it established a permanent presence on the Moon. But it does not need to. The Chinese government need only interpret the Treaty, and particularly the concept of “due regard” in a manner that will satisfy its strategic goals.

If a Chinese spacecraft lands, or even crashes, in a mineral-rich area of the Moon or another celestial body, how will the Chinese government interpret its rights and obligation? How will it define “due regard?” While the future actions of the Chinese government cannot be predicted, we can learn from past statements about space and acts taken on Earth and in Low Earth Orbit.

- The US-China Economic and Security Review Commission observed that “China seeks to control access to the Moon for strategic aims.”
- The Chinese government’s space policy has evolved subtly but tellingly.
  - Its 2006 White Paper, states that “China’s government holds that outer space is the commonwealth of all mankind, and all countries in the world enjoy the equal right to freely explore, develop, and utilize outer space and celestial bodies.”
  - Its 2011 White Paper report leaves out language on space as a commonwealth, reading instead that the “Chinese government believes that the free exploration, development and use of outer space and its celestial bodies are equal rights enjoyed by all countries in the world.”
  - It’s 2016 White Paper replaces the phrase “free exploration” with “peaceful exploration” though it does maintain that all countries have “equal rights” to explore.”
  - It’s 2021 White Paper opens with the statement that China’s “eternal dream” is to “explore the vast cosmos, develop the space industry and build China into a space power.” It acknowledges that “peaceful exploration,

development and utilization of outer space are rights equally enjoyed by all countries.”

- China’s Earth activities indicate a willingness to disregard norms and act decisively even in the face of international objection. For example, the Chinese government has made sweeping territorial claims over virtually the entire South China Sea, and appears willing to defend these by force. It is not difficult to imagine similar actions being taken with respect to an installation on the Moon or another celestial bod, especially under the cover of “due regard.”
- China is not a responsible or transparent space actor.
  - While the majority of US spacecraft share information regarding their planned maneuvers to a global database to support space domain awareness and space traffic management, the majority of Chinese spacecraft do not.
  - Chinese space objects routinely enter the atmosphere with little guidance or control.
  - Chinese launches often cause damage in local environs.

In a worst-case scenario, a first mover like China can block access to extraterrestrial resources under the legal cover of the Outer Space Treaty—particularly the concept of due regard as it has been conceptualized to support exclusion or safety zones.

#### **V. Conclusions and Recommendations: Acknowledge Extraterrestrial Resources**

The space beyond Earth is a domain of human activity. A domain filled with natural resources that can significantly improve life on Earth. This Hearing is a first but significant small step. US policy as a whole, and not just space policy, must acknowledge and embrace the vast resources that the Universe offers. In addition:

- The US should continue to encourage countries to accede to the Artemis Accords and create as large a coalition as possible.
- The US should continue to adopt licensing and regulatory actions that support transparency and responsibility.
- The US should increase support for commercial space activities that specifically include extraterrestrial resource extraction and utilization activities.
- The US should continue to actively participate in the COPUOS and, in particular, its Working Group on the Legal Aspects of Space Resource Activities.
- The US should work with Artemis partners to enable the research necessary to better define the concept of safety zones and due regard.

As Walter Cronkite said: “We are the lucky generation. We first broke our earthly bonds and ventured into space. From our descendants—perches on other planets or distant space cities, they will look back at our achievement with wonder at our courage and audacity and with appreciation at our accomplishments, which assured the future in which they live.”

We have a responsibility to the future to get this right, and I am confident we can.

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QUESTIONS SUBMITTED FOR THE RECORD TO MICHELLE L.D. HANLON, EXECUTIVE DIRECTOR, CENTER FOR AIR AND SPACE LAW, UNIVERSITY OF MISSISSIPPI AND PRESIDENT AND CEO, FOR ALL MOONKIND

#### **Questions Submitted by Representative Gosar**

*Question 1. How are space resources natural resources?*

Answer. Encyclopedia Britannica defines a natural resource as “any biological, mineral, or aesthetic asset afforded by nature without human intervention that can be used for some form of benefit, whether material (economic) or immaterial.<sup>1</sup>

<sup>1</sup> <https://www.britannica.com/science/natural-resource>

Merriam Webster states that natural resources are “industrial materials and capacities (such as mineral deposits and waterpower) supplied by nature.”<sup>2</sup> And while, as Britannica points out, what is considered a “resource” has varied over time and from one society to another, natural resource laws and policy categorize resources by their character and properties—and not by where they are located. Aluminum, beryllium, tungsten, zinc and many other critical minerals are natural resources wherever they occur, even if they occur beyond areas of national jurisdiction, whether that area is the high seas, or space.

Natural resources do not change their nature or their qualities based on where they are found. As the natural resources on Earth are depleted, as we know they will be over time, humanity must be open to looking for other sources and this Committee is well-placed to lead this paradigm adjustment.

*Question 2. How can the House Committee on Natural Resources help America secure the celestial mineral supply chain?*

Answer. The US Geological Survey (USGS), the administration of which is within the jurisdiction of this Committee, already implements activities beyond national jurisdiction as it is tasked specifically with researching seafloor mineral resources that occur in the high seas, domains recognized under international law as not subject to sovereign or territorial claim. This Committee can expand the parameters of this research to all areas beyond national jurisdiction, including outer space. As with research conducted on marine mineral resources, findings by the USGS about mineral wealth in space should be shared with stakeholders, including industry.

The fact that humans will deplete Earth supplies, even those found in the high seas, is inevitable. For example, in 2022, the USGS released a list of 50 critical minerals, natural resources, defined as those that are essential to the economic and national security of a nation but that have a supply-chain vulnerable to disruption.<sup>3</sup> Demand for these critical minerals is increasing, and one of the roles of the USGS is to address the need for more up-to-date information on access to critical mineral resources. The Committee could propose legislation to expand USGS research to include the space domain in its effort to define and prioritize focus areas with resource potential for these 50 critical minerals.

While some might argue that this is premature as we are many years away from being able to successfully mine natural resources beyond Earth, identifying mineral rich areas in space as soon as possible offers many benefits, among others: first, it provides an incentive for the development of space mining technology; second, it assures that once the technology is ready, we will know where to go; third, it can alleviate US dependence on foreign-sourced supply chains; fourth, as our understanding of human reliance on the ocean eco-system increases, we can avoid disrupting the marine environment with mining operations; and finally, understanding what resources exist in beyond Earth and how accessible those resources are can do much to alleviate present tensions regarding resources. If it is established that these resources are in great abundance, as we believe them to be, potential for conflict will wane.

It is also important to point out that the Chinese government has made very clear its intent to “Exploit the Works of Nature” through a public roadmap that sees “a comprehensive space resources system spanning the solar system by the year 2100.”<sup>4</sup> This is a long game and this Committee is well-poised to oversee US efforts in this regard. Space resource utilization is the future and we jeopardize that future with inaction.

The space domain is an international domain and as this Committee has jurisdiction over international fisheries agreements, the UN Convention on the Law of the Sea, and cooperative efforts to encourage, enhance and improve international programs for the protection of the environment and the conservation of natural resources, it is a perfect starting point to open discussion of how international cooperation in the management of the natural resources of space might be structured. The Committee should hold hearings on how to manage natural resources in the space domain under the framework of the international space treaty regime.

<sup>2</sup> <https://www.merriam-webster.com/dictionary/natural%20resource>

<sup>3</sup> <https://www.federalregister.gov/documents/2022/02/24/2022-04027/2022-final-list-of-critical-minerals>

<sup>4</sup> <https://interestingengineering.com/innovation/china-reveals-grand-vision-for-space-resource-utilization>

Finally, given the Committees jurisdiction over relations of the United States with Native American and Native American tribes, this provides the perfect opportunity to assure that Indigenous communities are included in the discussion of space resource utilization. The Committee can work directly with Indigenous communities to assure contribution from this group that is woefully under-represented in space activities.

### Questions Submitted by Representative Lamborn

*Question 1. What are the opportunities and barriers to greater coordination and investment in space resources research within academia?*

Answer. The United States has the finest academic institutions in the world and has always been at the forefront of both space activities and space governance. Three leaders come to mind. The Colorado School of Mines offers the only space resource graduate program in the world. The University of Mississippi has one of the oldest space law programs in the world and is home to the only ABA-accredited law school to offer a JD Concentration and an LL.M. in Air and Space Law. Finally, the Thunderbird School of Global Management hosts the only executive master of global management in space leadership program. Combining these three superlative and unique academic centers provide boundless cross-disciplinary opportunity at minimal cost to the taxpayer. Working directly with USGS, these three institutions could help lay the groundwork for a sustainable space governance framework that meets the requirements of international law without ceding US leadership in the space domain.

US leadership is vital because we have, at present, the most representative government in the world. Every human, wherever located, will be impacted by space resource activities. In the US we work hard to give voice to all humans—albeit not always successfully. Nevertheless, our system of governance provides more opportunity than any other in the world. If we want to see an equitable and fair management and distribution of space resources, we want to raise awareness and encourage discussion of all space activities.

The only barrier to greater coordination is the lack of funding and direction from the government.

*Question 2. This committee especially understands the necessity of specific but clear laws and regulations when it comes to mining. It is important to walk that fine line of providing guidance and oversight to the mining industry without stifling the growth. Besides the Artemis Accords, which we see NASA is using to set the standard for extraction of minerals such as these, what else should this body be working on to protect the rights of private companies to extract and sell these critical minerals?*

Answer. Given this Committee's jurisdiction over aspects of the Convention on the Law of the Sea and in particular the remit to encourage, enhance and improve international programs for the protection of the environment and the conservation of natural resources, this Committee should take an active role in developing the foundation for space resource management and utilization in keeping with US treaty obligations. While arguments have been made that anything space-related should be relegated to the House Committee on Science Space and Technology, this gravely narrows our perception of space and its importance in human society. It is this Committee that manages natural resources, and its jurisdiction should not be narrowed by where those natural resources might be located. Respectfully, this Committee cannot properly oversee the management of natural resources if it ignores such resources just because they occur beyond Earth and beyond sovereign jurisdiction. There exists an opportunity to assure that space activities truly benefit all humanity, and this Committee should seize it.

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Dr. GOSAR. Thank you very much, Ms. Hanlon. I thank all the witnesses for their testimony. I am now going to go to Members on the dais for their questions. I recognize the gentleman from Montana, Mr. Rosendale, for 5 minutes.

Mr. ROSENDALE. Thank you very much, Mr. Chair and Ranking Member Stansbury, for holding this hearing today. It is a very important subject. It underscores the urgent need to diminish our dependence on foreign adversaries for crucial minerals. These

minerals are essential to America's success in the 21st century, and we cannot rely on our enemies for them.

China is deeply invested in controlling the critical mineral supply chain. The more we rely on them for these resources, the more of a threat they pose to our sovereignty. It is especially concerning that the CCP is exerting its control on a global stage, increasing the possibility of a future dominated by China. Currently, the United States relies on China for 26 of the 50 critical minerals designated by the Department of the Interior as a cause for concern. China not only controls production, but also dominates the refining process, and hardly anyone is talking about that.

The United States finds itself at a crossroads. We must decide whether to reopen our mining and refining operations, regaining control over our destiny with respect to these critical minerals, or continue down a path of increased dependence and economic entanglement with the CCP.

Unfortunately, the current Administration seeks to import these minerals from countries that use child labor and produce emissions. We could mine critical mines ethically and cleanly now right here at home. But instead, we rely on third-world countries in the name of environmentalism.

I am intrigued by extracting minerals in space, especially as China races there. However, I want to ensure that this does not replace extracting the critical minerals in our own backyard.

One thing I have learned living in Montana, where everything is freight in and freight out, transportation costs are extremely expensive. Looking to space for minerals where they may be plentiful is interesting, but it will present incredible access challenges.

And to hear comments about how we have to make sure that the environmental standards are met, or that the public receives their funding back after they make the investments, I have a real big problem with that. I am a skeptic, I will be honest with you, because the nations that we compete with right now do not follow the labor or environmental standards that are in place with the international community as it exists, whether it be by norms or mandates. Yet, somehow this panel believes that they are going to follow those in outer space? You are kidding yourselves. You are absolutely kidding yourselves.

Mr. Autry, you begin your testimony by quoting, "Strategic minerals and manufacturing have always created new real wealth," and I agree with that, I absolutely do. America has handed that source of wealth to other nations. We have literally developed the technology and then handed it to them. Space is a new frontier and offers a second chance to reverse that error. Rather than focusing solely on space exploration, why not consider a dual course of action that combines space endeavors with domestic production in the United States?

How do you envision balancing the opportunities presented by space exploration with the immediate advantages of more cost-effective and less risk-intensive resource mining here at home on our own soil?

Dr. AUTRY. Thank you, sir. Excellent question. I want to be clear I don't know how you might have gotten the idea that the entire panel supports some of the things that you rallied against. I don't

think that that is the case. And I also want to be clear at no point would I have suggested that we do not pursue an aggressive development of U.S. resources in an attempt to rectify the mistakes we have made here on Earth with our global supply chain. That needs to happen.

Back in 2010, I wrote a book called *Death by China*. And in that book I addressed the issue of the Molycorp mine at Mountain Pass, California, which back around 2000 produced 80 percent of the world's rare Earth elements. China shut that mine down using aggressive dumping of products made with abusive environmental behavior in Mongolia and Sichuan, and then they jacked up rare Earth element prices, and then they managed to get control of the output of that mine, which is all shipped to China now. I tried to bring this to people's attention, and do you know what I got? "Do you realize we have an economic crisis here in the United States, and we have this problem and that problem? We don't have time to worry about that right now." Well, this is where we are in space. We need—

Mr. ROSENDALE. My time is just about up, Mr. Autry. What I am trying to say is that if we can't get those minerals produced here domestically when we have the technology, the labor standards, the environmental standards, why would you recommend that we take unlimited amount of public dollars to do it in outer space?

Dr. AUTRY. I didn't say unlimited at all.

Mr. ROSENDALE. I yield back, Mr. Chair.

Dr. AUTRY. I do believe investing in that technology will benefit us here on Earth.

Mr. ROSENDALE. I yield my time, Mr. Chair.

Dr. GOSAR. I thank the gentleman from Montana. The gentlelady, Ms. Kamlager-Dove, is recognized for 5 minutes.

Ms. KAMLAGER-DOVE. Thank you, Mr. Chair. It is always a new experience on this Committee.

China and Russia are exploitatively mining in Africa, and Russia is mining democracy and sovereignty in Ukraine, two critical national security threats that Republicans continue to slow walk when it comes to solutions, or even acknowledging that there are issues.

A couple of years ago, the movie "Don't Look Up" came out, and I can't help but bring it up now. The movie is about two scientists who discover that an asteroid big enough to wipe out all of life on planet Earth is headed towards us. The scientists tried to convince the U.S. Government to divert the asteroid, but they get sidelined when an eccentric billionaire convinces the President we should mine the asteroid for valuable minerals instead. A highly politicized asteroid denial campaign ensues. But in the end, facts win.

While the movie was widely known to be a satirical take on the threat of the climate crisis and the refusal of some to take it seriously, it looks like my colleagues across the aisle didn't get the joke. Nearly a year into Republican control of the House, and this Committee has yet to have a single hearing on the biggest threat of our time.

Just to remind everyone, 2023 will be the hottest year ever recorded, and not by a small margin. Extreme weather events like hurricanes in California, ice storms in Texas, and wildfire smoke

in DC are now the norm. Hundreds of thousands of people are dying each year, local economies are being destroyed, and frontline communities are getting hurt first and worst. Yet, many of my Republican colleagues still refuse to even talk about the climate crisis unless they can deny it. The idea of passing any climate legislation this Congress is a fantasy. In fact, every Republican who was here last year voted against the single biggest investment in clean energy and climate action in history, the Inflation Reduction Act.

Don't get me wrong. If space mining becomes a reality, we must be absolutely clear-eyed about how it is managed. The environmental, economic, and social issues are important and challenging. So, I am glad our witness, Dr. Milazzo, is here to document those issues into the Congressional Record. So, yes, it is an important conversation to be had in the Committee that can consider legislation about it.

Newsflash, that Committee is not this one. We repeatedly asked Republicans for a clear jurisdictional justification for it to be in this Committee and never got one.

Newsflash, today's hearing is not the most pressing issue for the American people. It is just one more attempt to get us to look away from their obvious inability to govern. They took 15 votes to pick a Speaker, voted him out, wasted 3 weeks to find another one, and are now turning on him. They have bafflingly turned one government shutdown threat into two. Their government funding bills are being shelved by their own party, and they are raining down investigations that generate Fox News headlines, but no actual or factual evidence of wrongdoing. With that kind of rap sheet, I can understand the need for a flashy distraction. I guess my Republican colleagues did learn something from "Don't Look Up" after all.

With that, I yield back.

Dr. GOSAR. I was hoping we would see a lot more questions to the panel instead of the pontificating that seems to come out of the West Coast.

The gentleman from Colorado, Mr. Lamborn, is recognized for 5 minutes.

Mr. LAMBORN. Thank you, Mr. Chairman, and thank you all for being here.

NASA and the U.S. Geological Survey have been working together to develop new technologies to detect and assess off-world mineral resources. Universities like the Colorado School of Mines, which hosts the nation's only space resources program, is also researching how to detect, assess, and utilize resources in space. These advanced technologies would likely have applications for domestic industries, as well.

Dr. Milazzo, how is NASA and USGS working with other Federal partners like the Department of Commerce and Department of Energy to advance technologies that could support a new generation of low-impact, critical mineral extraction and production here on Earth?

Dr. MILAZZO. Thank you, Congressman, for that question. I am hesitant to speak for either NASA or the USGS. I was an employee of the U.S. Geological Survey some years ago, but now I am no

longer a civil servant, so I hesitate to speak for them about what efforts they are working on right now.

The reality is that we have a lot of spacefaring, Earth-pointed satellites that are helping to better understand resources and resource availability across the Earth. So, the specifics of what the policies are and what the activities are right now, I am not fully informed of. So, I want to be careful I don't speak for either of those agencies at this time.

Mr. LAMBORN. OK, fine. Besides the investments we will need to make in technology, I know we will also need to be looking to academia to make investments in future jobs in space mining. In June, I co-lead H.R. 4152, the Space Resources Institute Act, with fellow Colorado Representative Caraveo. The bill directs NASA and the Department of Commerce to report to Congress on options for establishing an institute related to space resources, and to provide the necessary leadership in basic research, resource mapping, and technology development that could dramatically reduce the cost of commercial space missions, stimulate new industries, and maintain the United States' leadership in space.

Dr. Autry, what Federal support is needed to encourage and leverage private-sector investment and research into a more robust U.S. strategy?

Dr. AUTRY. Thank you. I do want to acknowledge the Colorado School of Mines' leadership on this topic, and my colleague, George Sowers, there, in particular. They have done great work.

As I stated in my testimony, I think reasonable amounts of R&D investment can help dual-use technologies that benefit mining both here on Earth and in space in a reasonable way. And it is not an excessive amount of money.

I also think that we can look at working with academia to make sure that we address the issues that my colleague, Dr. Milazzo, has while moving forward in a timely manner, as Michelle Hanlon has mentioned, because if we don't we will be ceding that field.

It is also super important to make sure that we recognize some mechanism under which the mining operation sites and processing sites on a celestial body can be transferable and collateralizable so that debt investment, as well as venture capital, can come into this field and run it like a normal industry when it does emerge.

Mr. LAMBORN. OK, very good. And I also sit on the Armed Services Committee. We are concerned about what China is doing to become more aggressive in the Pacific and, indeed, in the entire world. So, Mr. Sundby, what are your biggest concerns when it comes to the fact that China is also in this race to secure the potential of rare metals from space resources?

Mr. SUNDBY. My primary concern is that the Chinese military is there. The Chinese military essentially controls the entirety of their space program. Their space program has very little civil representation, essentially, and the People's Liberation Army is placed in authority to oversee their operations that will be conducted on the lunar surface.

So, when you see institutions such as the Lunar Research Organization that they have established with Russia, that institution will be staffed by military personnel. That is legal under the Outer Space Treaty, but it is highly concerning that that is the

institution that will be overseeing all of their research and resource utilization and exploration on the surface of the moon.

Mr. LAMBORN. Thank you.

Mr. Chairman, I yield back.

Dr. GOSAR. I thank the gentleman from Colorado. The Chairman for the Full Committee is now recognized for his 5 minutes.

Mr. WESTERMAN. Thank you, Chairman Gosar, and thank you to the witnesses for being here today.

And I do want to take a minute and reassert that the Committee does have jurisdiction on this issue. I know that has been questioned, but I don't think there is any question that our Committee does have jurisdiction on this issue.

And this is an issue that some people might ask why are we doing this, this seems far-fetched. You could ask the question, why not mine the Earth first, and then we will work on outer space later? But also, if we look at the past, people would have probably said the same thing about sending someone to the moon and the space race that we were in back then. And we know that there were some great discoveries and technological advances that came out of those efforts.

When I was going over this hearing with staff, I was joking and said, "Have they found dilithium crystals," being a Star Trek fan. And I know you haven't, but one question I want to ask is what are the possibilities of new advances or finding new materials and things that could be beneficial that we can't even imagine today?

And if you are a Star Trek fan, you know that there were things on there that seemed really far-fetched and sci-fi when the show was made, but a lot of those are things that are actually kind of in our world today with communications and other things. But what opportunity do we have to advance our scientific knowledge by proceeding with space exploration for mining?

And I will start with Dr. Autry.

Dr. AUTRY. Thank you, sir. And I do have to underscore I can't imagine why you are not allowed to discuss space resources in the Natural Resources Committee. This baffles me. I am also lost on the idea of why America can't, for once, have long-term thinking. Because every single problem that we have today, which we are so obsessed with solving today and is distracting us from the future, is because we weren't looking ahead of ourselves. We have been staring at our feet as we walk forward.

There are unknown opportunities out there, sir, that we don't know what they are. They won't be dilithium crystals, but they may be just as amazing. When we entered the first space race, nobody predicted GPS, the Internet, or that I would have solar panels on my house, or that we would have fuel cells backing up the operating rooms of hospital power supplies. These things all came down because of the investment we made in those technologies, and I don't know what we will discover.

There are some things that cannot be found on Earth that are found in the moon. The isotope helium 3 is one of the ones that has been discussed, and the head of the Chinese lunar program is very excited about that. He says that the equivalent of three space shuttle loads of helium 3 could power the entire Earth for a year with clean, non-radioactive energy. That is worth looking at. That

material is very, very hard to find on Earth. It is like 100 parts per billion in natural gas reserves in the Earth, but it is fairly relatively abundant in the moon's regolith.

Mr. WESTERMAN. That leads into another question I had. I have been to several mining operations, and it is amazing the small amount of rare Earth elements that you find in a ton of ore. I mean, you are talking about ounces or less. Are there greater concentrations of these minerals and elements that you find in space than we could find here on Earth?

Dr. AUTRY. Indeed, and one of the most important things to realize, and that Michelle Hanlon touched on, is these are concentrated. I mentioned the large mass concentration near the south pole of the moon in the Aitken Basin. That may be 90 percent of the moon's mineral resources in that one spot. China or Russia could go build their lunar base right there, and there is a good reason to believe they will, and just exclude us from that in no time flat. Even if we are not worried about mining it for 50 years, we will have just signed off the future because we didn't deal with it today. So, those resources are likely to be concentrated, rather than evenly distributed. We need to get out there, as I suggested, and increase NASA's investment in the technologies and missions to identify where these resources are.

Mr. WESTERMAN. And, Ms. Hanlon, this idea of the global commons of the resources that are in space, we know about the tragedy of the commons here on Earth if we think we can't exploit a resource enough and you get too many actors, and at the end of the day you have exploited the resource. What is the danger of having this view of the global commons, that it is going to be there, we can wait, and we don't have to take any action now?

Ms. HANLON. Thank you sir. The global commons is indeed ripe for tragedy. If nobody has a vested interest, then nobody has an interest in protecting and being responsible with respect to that commons.

Here on Earth, we have seen a lot of issues with people not respecting the high seas. Unfortunately, that happens to be also one of our biggest rivals, China. When we talk about environmental concerns and being responsible, this is one of the things we need to think about in this space race. If China does get to create the base, and create a zone, and set up a property area—and call it what it may, we are not allowed to own property in space, but it is going to be treated like property, because what is property? Property is the right to exclude. And that is exactly what China is going to do. That is what China does here on Earth. And we have no reason to believe they won't do otherwise in space.

Fundamentally, the concept of global commons also suggests that nobody can own it. And as we look at the vast universe that awaits us, it is incredible, anthropocentric hubris to suggest that all of the universe is somehow the responsibility of earthlings, as if nobody else, nothing else out there exists. We need to think about space very differently from the way we think about things on Earth, because it is infinite. Thank you.

Mr. WESTERMAN. Thank you, Mr. Chair. I yield back.

Dr. GOSAR. I thank the gentleman. The gentleman from Georgia is recognized for his 5 minutes.

Mr. COLLINS. Thank you, Mr. Chairman, and thank you for holding this hearing. I want to follow up off of what our Chairman of the Full Committee said. As a matter of fact, it is not only in our jurisdiction, but we have held field hearings all across this country for the past 11 months dealing with critical minerals and mining.

And I would like to point out one thing, Mr. Chairman. I think it is rather obvious that, as well as in those field hearings, our colleagues on the other side of the aisle weren't even there for those, much less here for this one today. So, when someone did pop in, it is no wonder she is a little confused that we might have jurisdiction. It is the fact that they don't participate.

If I ramble on a little bit more, please forgive me, but I am going to tell you something. China is in a race with us, and I am sure that the American people know that. And if they don't, they need to know that. They have even stated that by 2045 or 2049 they want to be militarily, socially, economically, and even in space be dominant over the world. And we need to be cognizant of that, and we also need to be paying attention to it, which is why I am so glad that we are looking at things like what we are looking at today.

As a matter of fact, we have an Administration that wants us to go EV on everything. Yet, Mr. Chairman, they refuse to let us mine. I mean, we were in Minnesota earlier, and we were talking about the largest deposit in the world of critical minerals in a town up there that is drying up because they have been trying to get permits for 20 years, but they can't do it.

Over 80 percent of the critical minerals that we do process in this country are processed over in China by factories and smelters that are nowhere near green or as green as they could be. Yet, here we are, not allowing our own people. So, today I want to continue to focus on China.

Professor Hanlon, you stated that legal norms in space will be developed based on activity. Whoever is first to establish space resource management and utilization will establish the corresponding legal norms. Will the world benefit more from space resources if CCP controls the celestial mineral supply chain, or if the United States controls the celestial mineral supply chain?

Ms. HANLON. Thank you, sir. One of the greatest things about this country is that we have the opportunity for every person to speak, to talk, and to give their opinion. We have hearings, we have notice of proposed rulemakings. Everybody has the opportunity to contribute, whether they are an Indigenous person, whether they are a male, female, cisgender. It doesn't matter. You have a voice if you are American. In China, that is not the truth, and that is not how the Chinese Government works.

I believe that if the Chinese were to get there first, I can't predict what they would do, but we can look at what they do here on Earth. They suppress their own people. They make claims to high seas as a sovereign territory. If we want to see the equitable, responsible use of space resources, and see them managed in an equitable manner, we need them to be led by a country and countries that are part of the Artemis Accords, who will support freedom and democracy and equity here on Earth and in space.

Mr. COLLINS. So, it is safe to say that America should focus on first obtaining a first mover advantage over space mining so that it can control both the legal framework and resource utilization policies that will most benefit our country. Is that correct?

Ms. HANLON. I would say that it could lead in the development of the framework, yes.

Mr. COLLINS. Thank you. And if America lets the Chinese Communist Party secure control over the celestial mineral supply chain, then all other concerns are practically useless because the CCP will just do what it wants.

Ms. HANLON. Yes.

Mr. COLLINS. Regardless of any implications for others, right?

Ms. HANLON. Yes.

Mr. COLLINS. All right, thank you. Well, let's look at a worst case scenario, then.

Dr. Autry and Professor Hanlon, real quick, I know I am running out of time. What is the worst case scenario if China wins the race for space mining? And how would that negatively impact the United States?

Dr. Autry, do you want to start with that?

Dr. AUTRY. Yes, I don't want to be hyperbolic here, but if China wins the race in space we have ceded the strategic high ground militarily, and we have ceded the entire economic future, and the United States will be relegated to a backwater position for the rest of human history. I honestly think this is an existential point.

Mr. COLLINS. Thank you.

Professor?

Ms. HANLON. I agree with Dr. Autry. The Chinese will have the opportunity to block our access not just to the moon, but to all of space, and humanity's future lies in space. We have a lot of problems here on Earth to deal with, but a lot of the answers we will find in space, including, I believe, ultimately, peace. Thank you.

Mr. COLLINS. Thank you.

Mr. Chairman, I yield back.

Dr. GOSAR. I thank the gentleman. The gentleman from Arizona, Mr. Crane, is recognized for 5 minutes.

Mr. CRANE. Thank you, Mr. Chairman. It is an honor to be here.

I represent Arizona's 2nd Congressional District. We have a good amount of mining that takes place in my district. For those of you that don't know, Arizona is the largest mineral-producing state in the nation. It provides about two-thirds of our domestic copper. In May, the Biden administration stopped the opening of Resolution Copper in my district. This mine could provide 25 percent of the demand for copper here in the United States of America. It is kind of problematic.

I want to start with some questions for you, Mr. Autry. Is it a national security issue to buy critical minerals from our enemies, in your opinion, sir?

Dr. AUTRY. Absolutely, sir. And as I noted, I have been spending years talking about the rare Earth problem, and now everybody has woken up to that. I think they are going to wake up to the copper problem and the rest of these problems.

If we tie our own hands behind our back in the geopolitical and economic competition of the future, we are going to have a very hard time of it.

Mr. CRANE. Is it also an economic issue, Dr. Autry?

Dr. AUTRY. Absolutely. As I noted, having access to a reliable supply chain of factor inputs is critical, and China has demonstrated that they will change the prices to suit their needs to grab excessive monopoly rents once they have gained control over the global supply chain, and they will also cut us off or any other country off when they have the opportunity to leverage us politically.

They, for instance, quietly stopped all rare Earth element shipments to Japan several years ago in order to punish Japan for arresting a shipping captain who had rammed one of their coast guard ships. And they continue to behave that way.

Mr. CRANE. Dr. Autry, what about outsourcing these jobs? What happens to these mining communities when we shut down a mine and then send that overseas?

Dr. AUTRY. We have in this country, unfortunately, denigrated and not supported our productive industries and manufacturing and resource extraction. It used to be that you could go get a decent job to support a family right out of high school in one of these industries.

Mr. CRANE. Yes.

Dr. AUTRY. You can no longer do that. And we wonder why kids run up \$200,000 debts and they are fighting over jobs at Starbucks. It is because of our lack of respect for these industries and jobs.

Mr. CRANE. OK, so we have already covered it is a national security issue. It is an economic issue. Is it an environmental issue, as well, Dr. Autry?

Dr. AUTRY. Yes, absolutely. As the other Member mentioned, China doesn't do this well. In Mongolia, where they processed rare Earth elements using an incredibly destructive acid leaching process, the BBC did an article on it. They described it as the worst place on Earth, this toxic lake of sludge and mess that China is doing because China is willing to destroy their environment and our global environment in order to gain competitive advantage. The United States would do it right.

Mr. CRANE. The BBC? That is no right-wing outlet, is it, sir?

Dr. AUTRY. Yes, it is a crazy, conservative journal, I think.

Mr. CRANE. So, we have national security. It is an economic issue. It is an environmental issue. Sir, why would we be doing this?

Dr. AUTRY. Because the Chinese are putting a lot of pressure quietly on a lot of people in our country to be focused only on short-term things, to be fighting each other, and to not be paying attention to the strategic issues of the future.

Mr. CRANE. Yes.

Dr. AUTRY. And we have seen that manifest here today.

Mr. CRANE. They do put a lot of pressure on influential people in this country, don't they, sir?

Are you familiar with what "elite capture" is, Dr. Autry?

Dr. AUTRY. Absolutely. In fact, I testified to the House Foreign Affairs Oversight Committee back in 2013 on Chinese perception

management in the United States. I wish I could say the situation had improved since then, but it has not. There are a lot of people in industry politics that are at various levels compromised by the Chinese Communist Party.

Mr. CRANE. Yes, that is right, sir. Dr. Autry, does it bother you at all, does it concern you at all that this President and his son have taken money from the Chinese?

Dr. AUTRY. I am hoping, frankly, to keep space as a non-partisan domain, which has been very successful. Certainly, personally, I am concerned about that issue and any politicians where we would find that they were being paid odd consulting fees in tens of millions of dollars to do who knows what for a foreign government.

Mr. CRANE. Yes. Thank you, sir. I think we should all be concerned about it, and not focus on some of the distractions that were just brought in the room regarding we need to be focused on climate change. You want to talk about distractions? That was a complete distraction.

Thank you guys for coming. Thank you, Dr. Autry.

Mr. Chairman, I yield back.

Dr. GOSAR. I thank the gentleman from Arizona. The gentleman from New Mexico, the Ranking Member, is recognized for 5 minutes.

Ms. STANSBURY. Thank you, Mr. Chairman.

With all due respect to the comments that were made at the last round of questioning, if we are going to talk about Members of Congress being compromised by elite interests from other countries, how about we talk about members of this Committee who take campaign donations from multi-national mining companies that the Chinese Communist Party has an interest in, including in Arizona?

So, this is an important issue. Mr. Milazzo, I am really grateful that you are here to talk about the ethical issues concerning the future of space mining. But it is hard, listening to this conversation, to really get a sense of what we are talking about here. So, can you please help us understand? What kind of minerals are we talking about mining?

Dr. MILAZZO. Thank you for the question. In space, in our near-Earth space, whether it is the moon or asteroids, or even the asteroid belt, or even all the way out to Mars, most of the minerals that we can find here on Earth are going to be found somewhere else in space, as well. Not all of them. Some of the minerals that we find here on Earth require geologic processes like hydrothermal systems to concentrate those minerals into a valuable ore, something that we can—

Ms. STANSBURY. But just specifically, what are we talking about? Titanium? Platinum?

Dr. MILAZZO. We can talk about platinum group metals, golds and we can talk about cobalt, we can talk about most of the strategic minerals that have been discussed are somewhere available, for the most part, in space, as well as here on Earth.

Ms. STANSBURY. Got it. Yes, I was actually talking to a colleague who is a scientist who works at NASA about this issue over the weekend, and he was talking about asteroids that have been found that are high concentrations of platinum that themselves, these

asteroids, are actually worth trillions of dollars if they were to be captured, mined, processed, and sold here on Earth.

But I think part of what gets lost in this conversation is that we are talking about commodities that sell on international markets, and the price of those commodities actually, like all commodities, has to do with supply and demand, right? So, if we were to flood the global markets with supply and demand, it would impact all of these issues.

But I guess I am still struggling technologically and feasibility-wise, like, how far out is this? Even if we were to accelerate R&D in the United States and use international partnerships, how soon would we be able to tap these resources?

Dr. MILAZZO. I think that is a great question, and I think it is a really difficult one to answer perfectly. We have companies that think they can go mining next year or 2 years from now or something like that. I think that is totally unrealistic. I think we are looking at decades, at the best, to actually return valuable amounts of materials to some kind of use, whether that is use in space or back here on Earth.

Ms. STANSBURY. So, we are talking decades out. And, for me, I think part of what is hard, my background is in the sciences. I have worked in natural resources management my entire career. And the COP UN climate negotiations just wrapped up. And what we know, what the science is telling us, is that Earth is transforming so rapidly right now because of human emissions and the changes to our atmosphere that if we don't take immediate action, literally right now, in the next several years, we are not going to have a planet to live on.

So, as we are talking about trying to compete with China and get to these minerals first, and establish our claims, and to hell with global commons and celestial commons, we have some real issues here on planet Earth that we have to deal with right now. So, I think part of what I really struggle with, and I am all for R&D, I really, truly believe that we should be investing in R&D in all opportunities, and I understand the importance of competition. But my question is, can this mining be done, which it sounds like is being proposed by private companies, without Federal subsidization?

Dr. MILAZZO. I think that is a great question, and I don't believe so. I think eventually, maybe yes, but I don't believe that there is a high-enough return on investment on the time scales that most investors are looking for to realistically bring profits back to those investors without some kind of support from public funding.

Ms. STANSBURY. Yes. I mean, I think that is where it comes back to, we are talking about jurisdictional issues here.

Our role is to be good stewards of taxpayer dollars. So, at the end of the day, we have to ask questions like does it make sense to spend billions of dollars in Federal taxpayer dollars, which I think both of us across both sides of the aisle agree we should not be wasting taxpayer dollars on pursuing things that are not going to return a real value to the American people, especially as we are facing immediate crises. Should we be spending millions, billions of dollars to pursue R&D to subsidize private companies who are going to go then and capture those resources and use them for

their own profits? And I think that is, really, the ethical, the public policy question in front of us.

And the more immediate question is how do we solve the problems that we have on Earth and use the resources we do have to do so in a smart way?

Mr. Chairman, I know I am out of time, but I definitely would like to have another round. Thank you.

Dr. GOSAR. Thank you to the Ranking Member.

Mr. Sundby, your testimony discussed the private sector's role of, going in right after the Ranking Member's, in space resource development. How does the commercial space sector provide America a competitive strategic advantage, particularly as it relates to space mining?

Mr. SUNDBY. Yes, well it is central. This will not be done by the government. And to address some of the concerns regarding public funding, I do want to let everyone know that most of the innovation in this country with a multitude of our startups are funded by public grants, right? The problem with that is that it has become entrenched, and venture capitalists generally do not fund many companies that have not already received public investment or public grants. So, that has created a system that has been very reliant upon the government.

That being said, I believe that the commercial space sector, and particularly commercial companies that are focused on dual-use technologies, and I want to emphasize dual-use that will benefit the Earth mining industry, it will allow us to better extract these minerals in a more environmentally friendly way, and it will benefit our nation. If we can focus on those dual-use technologies and these space companies can utilize those, that will, obviously, give us a massive strategic advantage both here on Earth and in space.

And to that point of dual use, I do want to say this: mineral extraction, particularly lithium, is extremely environmentally degradable. So, the process of creating batteries and moving us towards electric vehicles is an admirable one, I fully support it, but there are problems with the extraction of this critical mineral here on Earth, and we need to be looking at options as we move forward, because it is still impacting our environment, moving from one form of energy to another. Thank you.

Dr. GOSAR. So, in your opinion, it takes a lot of energy to look at this aspect. Would that be fair to say?

Mr. SUNDBY. Yes, sir.

Dr. GOSAR. Immense. That is why the helium aspect is so important to the Chinese, is it not?

Mr. SUNDBY. Yes, sir, absolutely.

Dr. GOSAR. Because this is demonstratable fission, if I am not mistaken, right?

Mr. SUNDBY. It is nuclear fusion technology. It is generally theoretical, but there are numerous amounts of physicists that are very certain about its future, and we are becoming much closer to achieving it. Then the access to helium 3 will, obviously, be a mineral race, one likely that we have never seen before.

Dr. GOSAR. Got you. So, the United States has a permanent base on the moon, right? True or false?

Mr. SUNDBY. No, that is false. We do not——

Dr. GOSAR. Well, how about China?

Mr. SUNDBY. China is preparing. They have outlined their——

Dr. GOSAR. Dark side of the moon, right?

Mr. SUNDBY. What was that?

Dr. GOSAR. The dark side of the moon.

Mr. SUNDBY. They have looked at strategic locations, generally in the south polar region, which is where we believe they will place their international lunar research station. That is also the same region that we have looked at, due to strategic access to water ice.

Dr. GOSAR. Now, private sector, I think in the discovery, I would love to get back to first to discover instead of first to file. That would be so opportunistic for us to do.

But dentistry, I can tell you right now, has benefited from space. The tiles for re-entry on the space capsule, those changed the whole concept of ceramics. The density became much greater, much stronger, and you could cut colors with it, which is amazing. So, that was big, revolutionary.

The other aspect was memory wire, where you could actually put a wire in a refrigerator, you plot the bands where teeth are needing to move, and you put that band in there and see the patient a year later, and the teeth are magically in place. So, it is amazing what space has done, and we have always looked at that from that standpoint.

Now, Ms. Hanlon, if China were to get the upper hand, would we ever get a chance to get it back, from your viewpoint?

Ms. HANLON. From my viewpoint, no, we would never have the chance to get it back.

Dr. GOSAR. Dr. Autry, I heard a lot about these laser-type products. How close are we to those in space?

Dr. AUTRY. I am sorry, repeat that.

Dr. GOSAR. These lasers, these military lasers, from your understanding, how close are we to seeing this a reality?

Dr. AUTRY. The Chinese have already used laser weapons against U.S. satellites from the ground, and they are certainly entirely practical to use in space, as well.

Dr. GOSAR. It could be a game changer, right?

Dr. AUTRY. Absolutely.

Dr. GOSAR. Yes. We are going to do a second round. So, the Chairman of the Full Committee is recognized for his 5 minutes.

Mr. WESTERMAN. Thank you, Chairman Gosar. And, again, I appreciate the witnesses taking some extra time.

This is an emerging field, new concepts, a lot of unknowns. As I mentioned earlier, the common sense with what we know today might say that it might not be a good investment, but there is possibility that it could be a tremendous investment. So, just to maybe inform the Committee more and to give you a chance to talk about something you may not have gotten asked, I wanted to start down on this end, and is there some question you wish you would have been asked today that you haven't been asked, or something you would like to leave the Committee with?

Mr. SUNDBY. Yes. I would have liked to be asked what is the role of the space force in all of this, and that is a question that I think

many people do have. They are curious about this new service that we have.

As I mentioned earlier in my remarks, the Chinese have created a space force. They didn't call it a space force. It is called the Strategic Support Force. But they are paying attention to this matter. They are investing in this matter. They care about this matter. And as much as we have made advancements in this, we do shy away from discussing the difficult topic of our humanity from different nations going into space and being in that environment, and having to protect our assets from a security perspective.

So, my answer to that would simply be that we need to look at the space force and think of it more so how our Navy secures the high seas and allows for our shipping lanes and our conduct of industry and commerce in the ocean the same way that we will in space. So, we need to look at the space force from that perspective. We need to give it the ability to conduct that operation and understand that that will be under its purview as we go forward and further into space.

Mr. WESTERMAN. Thank you.

Dr. Autry?

Dr. AUTRY. Sure. The topic I would love to address is the use of public funds in helping us capture this industry before our competitors do. I am fearful that some on the Committee would not have funded the Lewis and Clark Expedition because it was a distraction from whatever problems were going on in the East Coast at the time and cost too much money.

I have heard the phrase "unlimited money" and "billions of dollars" tossed around. I want to be clear. We are talking about millions of dollars in research budget at the university level to help develop, again, dual-use technologies that will benefit us here on Earth and in space at the same time. And that should be one of the criteria that is applied to it.

If you give money to NASA to help them do additional research on space resources on the moon and on asteroids, they have done remarkable things for, again, millions or hundreds of millions of dollars. We are not talking about billions of dollars in the programs in any way.

And one of the great things about space is that the entrepreneurial revolution that has been going on is making space cheaper. The cost of access to space, space launch, and the cost of satellites has been dropping year, after year, after year, because we are commoditizing and commercializing something that used to be a government-run, bespoke program. So, this is not going to be expensive, and it is going to return benefits back to Earth.

When somebody decided to do GPS, they were thinking about how can we help American troops or put smart bombs through a window. And nobody thought that it would create Uber, and that it would create Pokemon Go, and that it would be in everybody's pocket, and everybody's car, and every boat.

Mr. WESTERMAN. And along those lines, quickly, I have seen various numbers on the return on public investment in R&D. Do you have an off-the-cuff number?

Dr. AUTRY. Sure, yes, I will give you my favorite number. Motorola did a study a dozen years ago on the value of GPS to

trucking fleets in the United States, and they determined that a truck is \$52,000 per year more efficient if it is GPS-equipped, fuel, tires, driver time, et cetera. We have a million of those trucks in the United States. That is \$52 billion a year the United States gets back from its investment in just one space technology that happens to be about the same as the entire U.S. expenditure on space every year.

Mr. WESTERMAN. Exactly. And it is amazing to me that we would argue that investing in R&D is a bad investment.

Mr. Milazzo?

Dr. MILAZZO. Yes, thank you for the question. I appreciate the opportunity to speak.

One thing that kind of makes me sad here is that we actually have the opportunity to reach across the aisle and agree on quite a number of things that we are talking about here. We have talked about dual use, we have talked about ethics. We have talked about a lot of things that we seem to agree on, on both sides of this aisle here, and yet there is still a lot of acrimony.

We can do lots of good for the environment while we are building up our capacity to mine in space. It is not going to happen tomorrow. It is on our doorstep, sort of, but it is not science fiction anymore. But at the same time, we are talking about dual-use technologies and approaches to making space mining accessible. You cannot do that without doing it here on the Earth.

So, we have to approach this in a collaborative manner, rather than an acrimonious manner. My fear is that we are going to lose the ability to do both, improve our mining here on Earth, improve our environmental protections here on Earth, and lose our ability to do space mining simply because we are fighting and we can't come to some real agreements that we actually agree on across all of the different political spectrums.

So, it makes me a little bit sad that we are having this fight when we don't really need to have it. We could come to a really good set of bipartisan agreements here, tri-partisan, multi-partisan, whatever, and really build a functioning standard for both mining in space and improving our mining here on Earth. Thank you.

Mr. WESTERMAN. I am out of time. I don't know if you want to allow Ms. Hanlon to answer that or not.

Dr. GOSAR. The gentlelady from New Mexico is recognized for—

Ms. STANSBURY. Aren't you going to let her answer?

Dr. GOSAR. You can let her answer.

Mr. WESTERMAN. All right, Ms. Hanlon.

Ms. HANLON. Thank you very much for the extra time.

I would like to address the concept of why we are discussing space mining now, when we don't think we are going to see a return or even a piece of metal within 60, 80 years. The fact of the matter is that the technology that we are developing to mine other worlds can be used to benefit humanity here on Earth already. These technologies can be used to help us get into mines with robots instead of little children. The mining for water in particular may help us find water here on Earth in pockets where we have the driest areas. Extracting and using off-Earth resources is going

to make it easier and more efficient for us to explore more of the universe and maybe find those dilithium crystals.

So, we have to think about this not just about what the end goal is, but all of the things that we achieve on the way. And as we have seen, NASA puts out a magazine every year of all of the technologies that we have benefited from because they were either developed for space or they were spin-off technologies of stuff that was developed for space.

The opportunities that are presented by space mining technology are truly boundless. Thank you.

Dr. GOSAR. I thank the gentleman from the Full Committee. The gentlelady from New Mexico, the Ranking Member, is recognized for 5 minutes.

Ms. STANSBURY. All right. Thank you, Mr. Chairman. I want to dig in just a moment about the budget, and R&D, and spin-off technologies.

I am a huge proponent of Federal R&D to help support economic growth and opportunity. I think part of why you are seeing some partisan back-and-forth on this Committee is that this is a hearing that actually should be in the Science and Space Committee, which is actually a bipartisan committee that works a lot on these issues of space technology. So, it is very unusual to have a hearing on this topic where we deal with public lands and waters. So, there is a real, I think, jurisdictional question, though I do respect the Chairman for his perspective on this. But I think that is part of the issue.

I used to work at OMB. I used to do the Earth science for the budget for the Department of the Interior. That means I did USGS' budget and I worked on satellite budgets. And the Federal Government spends billions of dollars every year subsidizing commercial space exploration and technologies. It is billions. And space mining research and technology done at universities through NSF grants is a very small subsection of Federal R&D monies.

And certainly, there are lots of spin-offs that come from Federal R&D. And I am glad the Chairman mentioned the heat resistant tiles because my grandfather, John Stansbury, who was an engineer, actually worked for the plastics company that perfected those tiles. So, we have a medal from John F. Kennedy that is still in my family from that era.

But there are legitimate questions here, public policy questions about where we spend our money in the near term and the long term, and also how we approach this question of the commons, and where we prioritize our funding, and whether or not it makes sense to try to out-compete China by unilaterally spending billions of dollars to help subsidize a private industry that is 60 to 80 years out in the future, rather than using international cooperation to try to pursue this.

And I think this goes to the bigger questions that the United States has engaged in since the onset of the Cold War and the arms race, and the militarization and commercialization of space. And space is a commons. There are different treaties, of course, that govern it. But certainly, when we started sending satellites up into space we just thought it was a vast unknown space where we could just put whatever technology up there. And now we have

literally thousands of space junk objects in space that are a hazard to both our military establishment, as well as the private sector, because we did not regulate those commons. So, now it is a huge and massive problem for all of us.

But I also think it is important to acknowledge that we are not going to out-China China. I mean, first of all, China is a state-run economy. Almost every enterprise in China has some tie to the Communist Party, right? It is a state-run economy. China is also an authoritarian, non-democratic place at this particular moment. Part of why they have been successful in undertaking aggressive economic activity on every single continent and now in space is because it is not a free place right now.

And the United States is a democracy. And we do have free enterprise here. And while I do support using Federal dollars to help support R&D, and exploration, and pursue ideas that are important to the future, we are not going to out-compete China on this particular issue in this particular moment.

But what we do know is that we have to solve our problems here on Earth. And I think that part of why we are seeing, as I said, contentious conversation here in this Committee is because this Committee's jurisdiction is really about solving problems on Earth, not in space.

So, I appreciate all of your comments, and I yield back.

Dr. GOSAR. I thank the gentlewoman. If we are going to pay our fair share and we talk about benefits, we ought to be bringing up the OPT program, the Optional Practical Training program. Here is where the biggest of businesses get the biggest bang for the buck. They don't put their money into the Social Security and Medicare fund, but they are treated like everybody else. So, if we are going to go down that line, we better take care of that.

Ms. Hanlon, can you elaborate basically on Article II of the 1967 Outer Space Treaty? The question I have is can you elaborate on how any country or private party can establish a resource extraction operation if territory cannot be claimed on a celestial body?

Ms. HANLON. Yes, absolutely. Article II says that no territory in space may be claimed by any nation by sovereignty or by any other means. Therefore, while we do have a structure where we have this freedom of access and use of space, we are not permitted to actually plant a flag and say, "This is mine."

Again, the concept of property is an exclusion one. We don't want people to come in, and not necessarily for malicious reasons, but because, for example, on the moon, the lunar regolith is very, very destructive. And if somebody drives too close to another operative machinery or one of our heritage sites, we will see a lot of damage done to that machinery.

The interesting thing, the conflict within the treaty is that Article XII of the Outer Space Treaty actually anticipates that countries will have habitats and installations on other celestial bodies. And it states in Article XII that you must give access to other nations to your installation on the basis of reciprocity. So, what we have in the Outer Space Treaty, what we have in international space law right now is a lot of conflict within the treaty itself about what it means. What actually does it mean when you

build an installation on the moon? What actually can you do? Can you exclude other people or not?

Dr. GOSAR. What makes it enforceable?

Ms. HANLON. There are no enforcement provisions under the Outer Space Treaty whatsoever. At this point right now, if there is an argument, a claim made, we must go through “diplomatic channels,” and those are arbitral. And then, after that, you can go to the International Court of Justice to an arbitral panel. Again, these things will take years to get through.

And the concepts, there is no bright line rule. We are using this concept of due regard, which is a balancing test, which means that even as you look at these issues, as we look for private investors in space, we can’t tell them that you can protect your property in space because we don’t know what due regard means.

Dr. GOSAR. So, without an investment, Dr. Autry, right now, what stops China from eliminating us from even being a player in this space?

Dr. AUTRY. Repeat that.

Dr. GOSAR. Yes. With some of the questions I asked you about the laser technology, what would stop us if we don’t get involved now in space from China eliminating us even being part of the process?

Dr. AUTRY. What we need to do is move quickly. We need to move with alacrity and, again, to address this issue of money. I never said anything about billions of dollars. If billions of dollars are being spent somewhere else, that is great. I am talking about a reasonable amount of money for the NASA science budgets, for the Department of Energy and NASA science work, and a reasonable amount of money for academic institutions to help solve problems here on Earth that will also be applicable in space. We need to do those things. We need to do them now, or we could be blocked from access to space, as Michelle said.

And I completely agree with Dr. Milazzo that we could have a very non-partisan agreement here among the panelists. The concerns he has are real concerns, and need to be addressed simultaneously to us moving forward with alacrity because we are in a race we didn’t necessarily choose to be in with a competitor who has proven to be a cheat here on Earth, and they are going to do that in space. And if we don’t move now, we are going to hand that field to them.

Dr. GOSAR. So, we are talking about dual use at Resolution Copper. My colleague from Arizona brought up Resolution Copper. Here is a company that spent \$2 billion just cleaning up a mine site, making sure they have all the water they need and all of that aspect. And here they were going to use robotics at 7,000 feet and below to mine this copper. This was going to be utilized for the future of technological mining on asteroids. That would be a dual use, right?

Dr. AUTRY. Absolutely, along with autonomous AI robots, as Michelle mentioned, to get the kids out of the cobalt mines in Africa, and power systems that Dr. Milazzo referred to that will have real benefits here on Earth.

Dr. GOSAR. So, I am going to get in another question. What is our dollar backed by?

Dr. AUTRY. Delusion.

Dr. GOSAR. There you go. But if we actually had a good supply of rare Earths, this could be a backing for our holding, monetary funding. That is how expensive and how important these are. We have even set up a consortium with Canada to try to get enough of these around.

Last but not least, I am aware of some different smelting processes that are now being pursued or actually pushed forward. Smaller, but they get everything out of the ore. Are you familiar with any of these?

Dr. AUTRY. It is not my area of expertise, but yes, I am familiar with advanced smelting processes. We have seen a revolution here in the United States going to electric smelting for steel, for instance, at Nucor Steel, and space technology presents the opportunity for us to explore unique smelting and processing applications.

Dr. GOSAR. Well, I just have to tell you, when I was a dentist, the ability to use ceramics on just a disease part was amazing. Amazing. I could put something in, and the color coding, I would say find it, and it is just amazing what is coming around with this technology. And you had firsthand knowledge of it.

With that being said, I thank all the witnesses for your valuable testimony and the Members for their questions.

The members of the Committee may have some additional questions for the witnesses, and we will ask you to respond to those in writing. Under Committee Rule 3, members of the Committee must submit questions to the Subcommittee Clerk by 5 p.m. on December 15. The hearing record will be held open for 10 business days for these responses.

If there is no further business, I adjourn this meeting.

[Whereupon, at 11:53 a.m., the Subcommittee was adjourned.]

[ADDITIONAL MATERIALS SUBMITTED FOR THE RECORD]

**Submission for the Record by Rep. Gosar****Statement for the Record****AstroForge, Inc.****INTRODUCTION:**

AstroForge is a commercial deep space mining company focused on extracting critical minerals from asteroids. Our mission is to autonomously mine Near-Earth Asteroids (NEAs) for precious and rare-earth metals with the intent of aiming to reduce the United States' dependence on foreign critical mineral supply chains. Our first mission, a prototype of our in-space refinery, launched in April 2023 and is currently in Low Earth Orbit (LEO). Our second mission, which will target, track, and image a Metallic asteroid approximately 30 million miles away, will launch in Spring of 2024.

Currently, the United States relies on geopolitical adversaries for these materials, sourced through traditional mining and refining methods.<sup>1</sup> Critical minerals like Platinum, Iridium, and Cobalt, are fundamental raw materials that modern technologies rely on<sup>2</sup>—they are abundant on asteroids<sup>3</sup>—but without steady access to supply and transparent pricing here on Earth, our technological progress and industrial base will be severely and irreparably weakened.

**IS ASTEROID MINING POSSIBLE?**

**Short answer:** Based on recent missions, advances in deep space exploration and technology, and coupled with the United States' trademark ingenuity, we think it will be very possible—not in 60 years, but before the end of this decade.

The skepticism around asteroid-related missions is understandable, given the complexity and novelty of space exploration. However, there have been several successful government-led missions to asteroids that highlight our growing capabilities in space technology and exploration.

The Japanese Aerospace Exploration Agency (JAXA) executed two successful missions, Hayabusa<sup>4</sup> and Hayabusa2,<sup>5</sup> which both collected samples from asteroids. The National Aeronautics and Space Administration (NASA) executed three successful missions, NEAR Shoemaker,<sup>6</sup> DART,<sup>7</sup> and OSIRIS-REx,<sup>8</sup> which accomplished a range of asteroid related objectives.

<sup>1</sup>See *e.g.*, Critical mineral resources of the United States—Economic and environmental geology and prospects for future supply: U.S. Geological Survey Professional Paper 1802 (Klaus J. Schulz, John H. DeYoung, Jr., Robert R. Seal II & Dwight C. Bradley eds., 2017), <http://doi.org/10.3133/pp1802>; Sara Schonhardt & E&E News, *U.S. Looks to Mongolia, Wedged between China and Russia, for Critical Minerals*, *Sci. Amer.* (Jul. 31, 2023), <https://www.scientificamerican.com/article/u-s-looks-to-mongolia-wedged-between-china-and-russia-for-critical-minerals/>.

<sup>2</sup>Notice of Final Determination on 2023 DOE Critical Materials List, 6450-01-P, U.S. Dep't Energy (July 28, 2023), <https://www.energy.gov/sites/default/files/2023-07/preprint-frn-2023-critical-materials-list.pdf>; Press Release, U.S. Geological Survey Releases 2022 List of Critical Minerals, U.S. Geological Survey (February 22, 2022), <https://www.usgs.gov/news/national-news-release/us-geological-survey-releases-2022-list-critical-minerals>.

<sup>3</sup>Kevin M. Cannon, Matt Gialich & Jose Acain, *Precious and structural metals on asteroids*, 225 *Planetary & Space Sci.* (Jan. 2023), <https://www.sciencedirect.com/science/article/pii/S0032063322001945>.

<sup>4</sup>Nat. Aeronautics & Space Admin., *Hayabusa*, <https://science.nasa.gov/mission/hayabusa/> (last accessed Dec. 26, 2023).

<sup>5</sup>Nat. Aeronautics & Space Admin., *Hayabusa2*, <https://science.nasa.gov/mission/hayabusa-2/> (last accessed Dec. 26, 2023).

<sup>6</sup>Nat. Aeronautics & Space Admin., *NEAR Shoemaker*, <https://science.nasa.gov/mission/near-shoemaker/> (last accessed Dec. 26, 2023).

<sup>7</sup>Nat. Aeronautics & Space Admin., *Double Asteroid Redirection Test (DART)*, <https://science.nasa.gov/mission/dart/> (last accessed Dec. 26, 2023).

<sup>8</sup>Nat. Aeronautics & Space Admin., *OSIRIS-REx*, <https://science.nasa.gov/mission/osiris-rex/> (last accessed Dec. 26, 2023).

Government-led missions to explore asteroids have been a huge success. However, past commercial ventures to mine asteroids have failed for two big reasons:

1. **Launch costs were too high.** 10+ years ago, launch costs were as much as 13,000% more expensive. This dramatic reduction in costs, coupled with a more robust space economy, allows AstroForge to use its resources on focused innovations.
2. **Focus on inefficient off-asteroid mining and refining.** Past commercial asteroid mining endeavors revolved around hauling large chunks of asteroids closer to Earth to refine them, which is simply not energy efficient or cost effective. Our proprietary approach to mining and refining asteroids in-situ is better.

There is still significant work to be done to scale these endeavors to match the capacity of mining critical minerals that would substantially benefit the United States. The path forward is getting clearer and can be strengthened with government support. We continue to innovate each day to make this a reality.

#### OUR APPROACH TO ASTEROID MINING

Boiling it down, AstroForge's innovative approach to mining in deep space involves three fundamental moments:

1. **Targeting Metallic Near-Earth Asteroids:** AstroForge aims to dock with these asteroids, which are primarily composed of iron, using electromagnets.



Figure #1—Round Trip Mission

2. **In-Situ Mining and Refining:** AstroForge plans to mine and refine precious and rare-earth metals directly on the asteroid. This process includes laser ablation, mass separation using mass spectrometry, and magnetic collection of the refined metals.

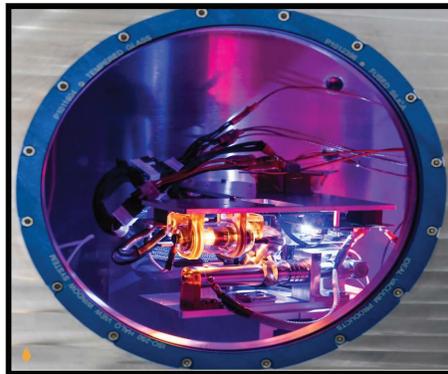


Figure #2—Prototype forge, currently in low earth orbit.

3. **Return to Earth:** After extracting approximately a metric ton of precious and rare-earth metals, which are currently valued between \$70M to \$100M, the mission will return to Earth.

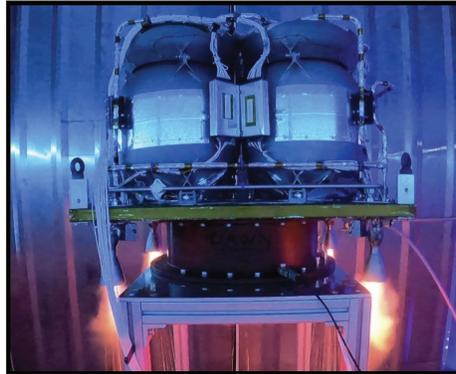


Figure #3—Launch vehicle test for second mission in 2024

Our ideal mission profile, illustrated in Figure #1, is approximately two years. In the ideal end-state of our technology, we will have many autonomous missions occurring simultaneously to maximize success and the volume of collection.

#### **WHY SHOULD THIS COMMITTEE ACT NOW?**

The House Committee on Natural Resources is uniquely positioned to support this innovation since space resources are natural resources. In the not-so-distant future, innovations in space mining will also trickle down into terrestrial mining, creating a dual-use innovation loop that the United States has successfully created in the past and led to ground-breaking technologies like GPS, memory foam, and LEDs.

Nearly all modern technology relies on precious and rare-earth metals. To keep pace with consumer demand, technological innovation, and a dwindling terrestrial supply, the United States needs to develop better ways to consistently access these critical resources. America's boundless innovation is its super power, however the raw materials to fuel that innovation could be a severe bottleneck to the future of computer chips, green technology, and energy independence. The Department of Energy has listed multiple precious and rare-earth minerals as "critical" on the path toward the United States' 2050 climate change goals.<sup>9</sup>

Our imperative to innovate is made even more clear by geopolitical pressures to our critical mineral supply chain. Right now, China and Russia control or influence the mining and refining process of many of the critical minerals on which American industry relies.

#### **AMERICA NEEDS TO BE THE FIRST**

The Chinese Communist Party (CCP) is trying to mine asteroids<sup>10</sup>—we need to do it first.

If asteroid mining is possible, the United States needs to have that first-mover advantage. The United States is already reliant on China for many critical minerals and we cannot risk ceding another major supply chain for these massively important raw materials.

<sup>9</sup>See U.S. Dep't Energy, *What Are Critical Materials and Critical Minerals?*, <https://www.energy.gov/cmm/what-are-critical-materials-and-critical-minerals#:~:text=Critical%20materials%20for%20energy%3A%20aluminum,silicon%2C%20silicon%20carbide%20and%20terbium> (last accessed Dec. 27, 2023).

<sup>10</sup>See e.g., Tim Marshall, *China's Bid to Win the New Space Race*, WIRE (Apr. 12, 2023), <https://www.wired.co.uk/article/china-space-race>.

In the off-chance that asteroid mining for critical minerals is not economically feasible, learning more about deep space and building commercial deep space capabilities still has enormous value. The United States cannot miss this opportunity for downstream innovations, instead we should reap their benefits.

#### **RECOMMENDATIONS TO CONGRESS**

Below are six recommendations to Congress that could rapidly advance deep space mining innovation for commercial companies in the United States.

1. Develop a strategy to support a broader commercial deep space economy that allows commercial companies in the United States to lead and innovate.
2. Provide funding for research and development for deep space mining, specifically for the critical minerals that the United States has deemed critical to industry and defense.
3. Allocate additional funding to NASA's Space Technology Mission Directorate (STMD), NASA Innovative Advanced Concepts (NIAC) Program, and NASA and JPL's Small Bodies Group, for the continued exploration of near-earth asteroids.
4. Clearly direct the United States Space Force to support and protect critical mineral supply chains in deep space.
5. Direct the Department of Energy to prioritize deep space mineral acquisition within their critical minerals innovation programs.
6. Urge the Department of Commerce to allocate CHIPS funding towards deep space mineral acquisition to bolster raw material availability for chip manufacturing.

#### **CONCLUSION**

AstroForge is ready to engage with the committee to further discuss its plans and the broader implications for U.S. leadership in space. We believe our mission aligns closely with national interests in technology, defense, and economic independence.

