Committee on Natural Resources
Subcommittee on Oversight and Investigations
Oversight Hearing
1324 Longworth House Office Building
December 12, 2023
10:15 AM

Oversight Hearing titled "The Mineral Supply Chain and the New Space Race"

Questions from Rep. Gosar for Mr. Eric Sundby, Co-Founder & CEO of TerraSpace, Executive Director of the Space Force Association:

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.

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:

i. 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.*

ii. 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.*

iii. 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.*

iv. 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.*

v. 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 from Rep. Lamborn for Mr. Sundby:

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 benefitting 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 timeframe, 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.

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.

i. 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).

ii. Second, the creation of more powerful energy sources and storage capability will assist in increasing the operational capacity of rovers, drills, etc.

iii. 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.

iv. 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 to 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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