Testimony of Dr. Moses P. Milazzo
Hearing on The Mineral Supply Chain and the New Space Race
Before the
Committee on Natural Resources
Subcommittee on Oversight and Investigations
U.S. House of Representatives
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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 spare 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 one 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.

Thank you,

Dr. Moses P. Milazzo

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