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Lunar Natural Resources: A Tour of a New Horizon

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September 22nd, 2023 (*http://www.jdsupra.com/?utm_source=lexisnexis&utm_medium=partner&utm_campaign=newstex* — Delivered by *https://newstex.com/?utm_source=lexisnexis&utm_medium=partner&utm_campaign=JD+Supra&utm_id=105411&utm_content=JSUP-105411-169542063994125876100079*)

With the success of the *https://www.cnn.com/2023/08/23/world/chandrayaan-3-lunar-landing-attempt-scn/index.html* this August, India became the fourth country to land a spacecraft on the moon. Improved fabrication methods like *https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Printing_electronics_to_help_space_missions_lose_weight* , plus larger-scale production of essential materials for remote activity, have made *https://www.internetandtechnologylaw.com/space-technology/* cheaper than ever to build. Even conservative investors are financing ventures, thanks to the moon economy's estimated *https://www.businessinsider.com/nasa-helping-private-companies-build-business-moon-make-lunar-billions-2023-6#:%257E:text=The%2520agency%2520is%2520tagging%2520private,be%2520game%252Dchanging%2520for%2520humanity.* near-term market value. Many of the planned endeavors are exploratory in nature, but they could pave the way for the eventual commercialization of the moon—namely, establishing permanent bases and mining lunar water and regolith (lunar soil).

The White House estimates that within 10 years, nations and private entities could launch up to *https://www.washingtonpost.com/technology/2023/08/19/russia-india-moon-landing-artemis/* . The National Aeronautics and Space Administration (NASA) plans to establish a pilot processing plant for lunar resources no later than 2032. In its Commercial Lunar Payload Services initiative, the agency has already contracted with 14 private businesses (including SpaceX, Lockheed Martin Space and Ceres Robotics) who are deep in development of the tools needed for moon infrastructure.

Other countries are pursuing similar plans. Canada is running a commercially driven program in cooperation with NASA. China has announced that in the next five years, it plans to employ a robot to lay down bricks for the first-ever *https://www.businessinsider.com/china-to-build-moon-station-five-years-lunar-soil-bricks-2023-4* . Even smaller nations like Luxembourg and the United Arab Emirates are seeking roles. This article digs deeper into the motivations, the methods, the critiques and the legal principles, as public and private sectors contribute to a new horizon of other-worldly enterprise.

Why Mine the Moon?

The initial motivations for space activity—scientific investigation, development of new technology, national security interests, and the sheer excitement of exploration—are still with us. But why would one undertake the expense and risk of natural resource development at such a distance?

Some resources might be economically returned to Earth. Materials rare on this planet but more prevalent on the moon, if valuable even in small quantities, could justify the round trip. Some argue that obtaining metals from space for use here is environmentally preferable to mining the *https://nautil.us/to-save-the-deep-ocean-we-should-mine-the-moon-238541/* .

The more compelling attraction is using lunar resources on the moon itself, as the springboard for further space development and travel. *https://www.nasa.gov/isru/overview* (ISRU), essentially the idea of living off the land, is a common goal. That entails harvesting lunar water—for consumption, for hydroponic agriculture, and for electrolysis driving breathable oxygen and hydrogen-based energy. Hydrogen rocket fuel is expected to be the basis for transport even deeper into space.

Finally, viewed from a long-term perspective, the risks of being on only one heavenly body exposed to asteroids and comets—or catastrophes of our own making—have come into focus. The dinosaurs died for want of a 'Planet B,' and so would we.

Key Resources

Among spacefaring nations and businesses, the most sought-after lunar materials include the following.

Metals and Minerals. Critical for technology like electric vehicles, wind turbines, cellphones and many other devices, rare earths are needed to support a low-carbon future. Scandium, yttrium and the 15 lanthanides all *https://www.reuters.com/technology/space/moon-mining-why-major-powers-are-eyeing-lunar-gold-rush-2023-08-11/* . Companies like *https://www.cnbc.com/2022/10/09/space-mining-business-still-highly-speculative.html* have set their sights on mining them and delivering them back home. Rare earths are useful in small quantities, so any level of production and transport from the moon could be an economic prospect. (In response, Julie Michelle Klinger *https://www.cornellpress.cornell.edu/book/9781501714597/rare-earth-frontiers/#bookTabs=1* that only a small fraction of rare earths are being recycled today, so going to the moon and back for more of them may not be as efficient as making better use of what we already produce here on Earth.)

NASA envisions a lunar *https://www.nasa.gov/directorates/spacetech/strg/lustr/NASA_Selects_Three_US_Universities_to_Develop_Lunar_Infrastructure_Tech* and has *https://news.bloomberglaw.com/federal-contracting/lunar-mining-dreams-prod-nasa-to-explore-space-tech-advancements* for university researchers to explore applications in 3D-printing. Also in partnership with NASA, *https://www.blueorigin.com/news/blue-alchemist-powers-our-lunar-future* aims to use metals extracted from regolith to generate solar power on the moon's surface.

The bulk of lunar material is common oxygen, silicon and aluminum. Metals are not typically concentrated, since the inert moon never experienced the geologic processes that led to our own lodes and veins. But a particular concentration rudely called 'KREEP'—potassium (K), rare earth elements (REE) and phosphorus (P)—occurs in the regions known as Oceanus Procellarum and Mare Imbrium.

Water. In 2008, scientists *https://www.planetary.org/articles/water-on-the-moon-guide* of water at the moon's poles, in the form of ice in shadowy craters. For those with lunar aspirations, those ice deposits have become a holy grail of sorts. Once extracted, the ice can provide drinking water for space travelers, and molecules can be split by electrolysis into hydrogen and oxygen. Hydrogen would power rocket fuel, allowing spaceships to launch off to Mars or beyond from the moon, and oxygen would provide air for living environments. Ken Wisian, a researcher at the University of Texas at Austin ***Bureau of Economic Geology***, has *https://www.beg.utexas.edu/files/content/beg/ext-aff/2022/10/Geothermal%20Energy%20on%20Solar%20System%20Bodies.pdf* how the combination of fluids and temperature differentials between the surface and subsurface could generate geothermal energy.

Helium-3. A *https://www.nytimes.com/2022/09/16/science/new-moon-mineral-china.html* recently returned to Earth with a moon sample containing helium-3. Though helium-3 is elusive on Earth, NASA estimates the moon is home to roughly *https://ntrs.nasa.gov/api/citations/20210012628/downloads/AIAA%2520ASCEND%25202021%2520Abstract_ADS*

Olson_210329.pdf of it. This element has been touted as a safer option than hydrogen isotopes like tritium https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Space_for_Earth/Energy/Helium-3_mining_on_the_lunar_surface#:~:text=Unlike%2520Earth%252C%2520which%2520is%2520protected,not%2520produce%2520dangerous%2520waste%2520products. . NASA is moving toward a small-scale prototype for an extraction system to bring helium-3 back to Earth. In the meantime, https://www.helionenergy.com/ is developing fusion reactors that make use of this rare material. In the https://www.vox.com/recode/2022/11/22/23473483/white-house-joe-biden-moon-artemis-permanent-outpost-spacex , NASA views helium-3 as a prime prospect to power nuclear energy on the moon.

The Mechanics of Moon Mining

While the allure of lunar resources is strong, excavating them is less straightforward. The paradox is that sophisticated technology is needed to get to the moon, but mining on the moon will be considerably less dependent on our modern contraptions. https://link.springer.com/book/10.1007/978-3-030-30881-0 has colorfully described the surprisingly low-technology methods that may be used.

Reduced gravity on the moon means that earthbound techniques will not work for off-world mining. Many mechanical extraction processes depend on our gravity level, and blasting would create near-permanent dust storms. Hydraulic mining is out of the question with water being a limited resource. Wide temperature oscillations and dust would wear out equipment and seals.

One finesse around these challenges is to keep lunar mining downright primitive—such as dragging a 'scraper' over regolith or ice before a resilient collection bag or a series of buckets called 'slushers.' Augers and plows could loosen the regolith. Other possible methods of releasing material include heat, mechanical stress, chemical reaction, electric spark, lasers, and solar power (imagine a series of mirrors and magnifying glasses like those in tomb scenes in the movies).

Once mined, these materials would likely need to be processed 'dry,' without water or other fluid, possibly with the help of separators, crushers or solar furnaces. Manufacturing on the moon would also likely work best if kept simple. Methods under consideration include layering or adhering metals on surfaces, akin to semiconductor manufacture, and 3D printing ('additive manufacturing').

To bring all this mining and production to fruition, a crucial component will be energy. Lunar explorers and developers will need a lot of it, produced from solar, fusion, fission or geothermal sources.

Prominent Players

With all eyes looking toward harnessing the moon's resources, the following countries and entities are among those actively planning lunar endeavors.

United States. NASA's Artemis project calls for putting astronauts back on the moon https://www.bbc.com/news/science-environment-64002977 . The U.S. has also https://techcrunch.com/2020/07/10/nasa-signs-agreement-with-japan-to-cooperate-across-space-station-artemis-and-lunar-gateway-projects/ with Japan, the EU and Canada, among others, to develop a space station (the Lunar Gateway) within the moon's orbit. It will serve as a support and research hub for lunar mining and production, and NASA hopes to populate it with its first astronauts in 2028. By 2032, the agency aims to establish a permanent lunar base.

India. In its bid to become a world space leader, India is preparing for a https://www.businessinsider.com/india-plans-send-humans-to-moon-celebrates-lunar-probe-success-2023-8%23:~:text=India%2520plans%2520to%2520build%2520on,said%2520Prime%2520Minister%2520Narendra%2520Modi. to the moon. This step will come after it launches test rockets over the next few years. In the meantime, the nation is analyzing two weeks' worth of data about the moon's composition gathered from its Chandraayan-3 rover.

Europe. In 2020, the Luxembourg Space Agency launched the https://www.esric.lu/ (ESRIC), a first-of-its-kind institution that focuses purely on the research and commercialization of space resources. It is strategically partnered with the European Space Agency (ESA). In addition to its work with the ESRIC, the ESA has been hosting an https://ideas.esa.int/servlet/hype/IMT?documentId=2b0622020c54f1ec99f9bee1218dc1f2&userAction=Browse&templateName= soliciting proposals for boosting ISRU in space. Though the ESA does not have any moon voyages currently on the docket, its terrestrial work is setting the stage for future space resource development.

China. The People's Republic says it will land humans https://www.space.com/china-astronauts-moon-landing-2030-plan by 2030, but it will robotically build lunar structures even sooner. It also announced it will partner with Russia to build a joint moon base by 2035, and several countries have agreed to participate in its International Lunar Research Station moon base initiative. Partners include Russia, Pakistan, the United Arab Emirates and the Asia-Pacific Space Cooperation Organization.

United Arab Emirates. After its initial moon rover was presumed lost in April 2023, the United Arab Emirates Space Agency says it is https://www.uaeusaunited.com/stories/uae-space-exploration#:~:text=The%20Emirates%20Lunar%20Mission's,electrically%20charged%20environment%20on%20the and will try again.

Russia. A longtime player in space exploration, Russia's latest moon mission ended in a crash landing this August. However the nation's space agency, Rocosmos, says it will https://www.space.com/russia-moon-program-continue-despite-luna-25-failure-putin-says , perhaps in 2025-2026. Whether its budget and capability can sustain such plans, given the country's status in the community of nations, remains to be seen.

A commonality in many of these space ambitions is a collaboration with—and reliance on—private sector tech companies. The commercialization of lunar exploits highlights the importance of space law.

Is it Legal?

Despite the global enthusiasm for moon travel and development, space mining projects face skepticism, scrutiny and opposition from a range of voices. Some worry about the long-term effects of https://nautil.us/the-moon-smells-like-gunpowder-261483/ on astronauts' lungs, while others view the potential https://www.nature.com/articles/s41550-019-0827-7 of interplanetary resources of any type as cause for alarm. https://www.sciencedirect.com/science/article/abs/pii/S0094576516311584 even claimed that extracting resources from space could devalue those materials on Earth—disproportionately causing economic harm to developing nations. Questions inevitably arise over the priority of space exploration compared with projects closer to home.

In any event, the potential use of space for human development and for extraction and use of resources is traversing uncertain legal territory. The United Nations (UN) https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html of 1967 says that space is 'not subject to national appropriation by claim of sovereignty,' without being very specific about resources and how they can and will be utilized. About a decade later, the UN's https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/intromoon-agreement.html provided that celestial bodies 'should be used exclusively for peaceful purposes, that their environments should not be disrupted, that the United Nations should be informed of the location and purpose of any station established on those bodies.' The agreement states that when it becomes feasible to extract lunar resources, international guidelines should be established under which there is to be ' https://www.unoosa.org/pdf/gares/ARES_34_68E.pdf .' But that pact was not ratified by most of the very countries that are now engaged in space exploration. In fact, Saudi Arabia has given notice of its https://www.mcgill.ca/iasl/article/moon-agreement-hanging-thread effective January 2024.

NASA more recently laid out the https://www.nasa.gov/specials/artemis-accords/index.html . Ratified by 29 countries as of September 2023, the Artemis Accords encourage peaceful moon exploration and contemplate 'space resource activities' by the signatories. China and Russia among others are not parties.

http://www.gil-gdi.org/regulation-space-resource-rights-meeting-needs-states-private-parties/ —including the United States (with its 2015 https://www.congress.gov/114/plaws/publ90/PLAW-114publ90.pdf), Luxembourg, the United Arab Emirates and Japan—have independently legislated legalizing celestial mining. The U.S. statute, for example, declares that mining activity and produced materials can be owned without creating national sovereignty—an interesting juxtaposition of principles.

Mark J. Sundahl, Professor of Law and Director of the Global Space Law Center at Cleveland State University, was part of the https://www.universiteitleiden.nl/en/law/institute-of-public-law/institute-of-air-space-law/the-hague-space-resources-governance-working-group on the topic of space development. He and Tanja Masson-Zwaan have helpfully summarized the https://kluwerlawonline.com/journalarticle/Air+and+Space+Law/46.1/AILA2021002 :

It seems likely that international and national law governing space resource activities will continue to evolve in parallel for the near future. The Outer Space Treaty provides general principles and does not, as most would agree, prohibit commercial use of space resources; the Moon Agreement is more detailed but of limited relevance because of the low number of ratifications. International soft law fills in some of the details, especially in terms of sustainability, but leaves other issues open. The development of national laws has so far been limited to a few cases, but they are more or less consistent and do not contradict international law.

History—from the California Gold Rush to changes in fisheries zones to the quest for metal nodules in the oceans—teaches us that the legal regime often follows the activity driven by technology, economics, and politics, not merely the other way around. We can expect that the law not only will shape, but also will be shaped by, the conditions of resource development beyond our planet.

Conclusion

NASA has described a ' https://www.jpl.nasa.gov/infographics/the-lunar-gold-rush-how-moon-mining-could-work ,' a description that, given history, showcases both the opportunities and the challenges associated with the prospect of rapid change. Space law (and space lawyers) will play an important part along the way, as rules are both applied to and modified by the brave new world of a commercialized, human-inhabited moon. In the meantime, participants in the sector will find themselves in a soft and shifting legal terrain.

[https://www.gravel2gavel.com/lunar-natural-resources/ .]

Notes

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