Congressional Research Service
Informing the legislative debate since 1914

Space Resource Extraction: Overview and Issues for Congress

July 29, 2024

Congressional Research Service
https://crsreports.congress.gov
R48144

Congressional Research Service
Informing the legislative debate since 1914

Space Resource Extraction: Overview and Issues for Congress

SUMMARY

R48144

July 29, 2024

Rachel Lindbergh
Analyst in Science and Technology Policy

Many in Congress have expressed interest in opportunities to extract resources (e.g., oxygen, water, precious metals) from the Moon, Mars, and asteroids—an activity often referred to as *space resource extraction.* The purpose of space resource extraction can be either to transport material to Earth for sale or to use the material while still in space (known as *in-situ resource utilization*, or ISRU). As of July 2024, only national space agencies have transported resources from celestial bodies to Earth, and in all cases, such resources were small samples intended for research purposes.

There are several existing programs within the National Aeronautics and Space Administration (NASA) that support research and development (R&D) for ISRU, primarily in support of the agency's Artemis program, as NASA hopes to use resources extracted from the Moon to make rocket fuel and water for astronauts. NASA also has several scientific missions to study asteroids, which may inform future space resource extraction. Other U.S. government efforts include research and natural resource mapping by the U.S. Geological Survey and studies on ISRU by the Defense Advanced Research Projects Agency (DARPA). Also, NASA has entered into contracts with four companies to collect space resources in the future, thereby establishing a precedent for private-sector space resource extraction. Several U.S. companies are also seeking to extract space resources for ISRU and for use on Earth.

Is Space Resource Extraction Allowed or Viable?

Disagreement persists over whether or not public or private space resource extraction is permissible. Under the Space Resource Exploration and Utilization Act of 2015 (P.L. 114-90, Title IV; 51 U.S.C. §51303), any U.S. citizen engaged in commercial space resource extraction is entitled to the resource obtained, in accordance with applicable law. The same law also directs the federal government to facilitate and promote commercial recovery of space resources.

Not all observers agree as to whether space resource extraction is allowed under existing international law. Some interpret the 1967 treaty commonly referred to as the Outer Space Treaty—the foundational treaty governing space activities, with over 100 signatories, including the United States—as prohibiting space resource extraction as a form of national appropriation. Others disagree, arguing that space resource extraction is not a form of national appropriation but rather falls under the treaty's provision allowing exploration and use of outer space by all. The Artemis Accords—a series of U.S.-led, nonbinding bilateral pacts initiated in 2020—state that their signatories may extract space resources and should do so in compliance with the 1967 Outer Space Treaty. Another treaty—the 1979 Moon Agreement—would prohibit the use of the Moon's resources until the international community develops a framework governing the equitable distribution of such resources. As of the date of this report, such a framework does not exist. The Moon Agreement has 17 parties, and the United States and other major space powers are not signatories.

Stakeholders provide varying assessments of the viability of space resource extraction. Some view the sale of space resources on Earth as potentially profitable, given that certain of them have high commercial value. Others are skeptical of the economic viability of transporting space resources to Earth but view ISRU as more viable, as it would reduce the costs of transporting supplies for deep space exploration. Yet others doubt the viability of any form of space resource extraction, due to the potentially high and uncertain transportation and development costs, as well as reliance on yet-to-be developed and tested technologies for extraction, management, and transport.

Considerations for Congress

The Space Resource Exploration and Utilization Act does not address which agency has regulatory or oversight authority for commercial space resource extraction. The Commercial Space Act of 2023 (H.R. 6131) would assign mission authorization for all "space objects" to the Department of Commerce, while the National Space Council has released an alternative proposal for federal authorization and supervision of "commercial novel space activities." Another possible issue for Congress is whether additional authorities are needed now or in the future to establish that private space resource extraction is conducted safely and with regard to U.S. international obligations. Congress may be concerned about ongoing discussions in international fora on space resources and how U.S. agencies are shaping these discussions. The appropriate level of federal support for R&D for space resource extraction may also be an ongoing issue for congressional consideration. Testimony at a 2023 hearing before the House Committee on Natural Resources called for federal funding for R&D on mining technologies that could be used on earth and in space, and funding for NASA space resource exploration.

Contents

Contacts

Introduction

Many in Congress have expressed interest in the potential for public- and private-sector entities to extract resources from the Moon, Mars, and asteroids—an activity often referred to as *space mining* or *space resource extraction*. There are at least three primary space resource extraction issues that Congress may consider:

- **How federal agencies might support research and development (R&D) of space resource extraction.** The National Aeronautics and Space Administration (NASA), the U.S. Geological Survey (USGS), and the Defense Advanced Research Projects Agency (DARPA) have programs that conduct relevant research or provide grant funding that may support the development of space resource extraction.
- **Whether and, if so, how to regulate and support potential private-sector activity.** There are several commercial U.S. companies developing space resource extraction capabilities.
- **Whether and, if so, how the executive branch might continue to engage directly with U.S. partners and allies and in international fora.** Various countries and their respective space agencies continue to discuss whether public or private space resource extraction is permissible under existing treaties and what an international governance framework might look like.

This report provides an overview of space resource extraction, relevant federal and commercial activities, and applicable domestic and international governance frameworks. It also identifies various perspectives on the feasibility and viability of space resource extraction. Finally, the report discusses selected considerations for Congress, namely, potential gaps in regulatory authorities, R&D funding, and engagement in international fora.

What Is Space Resource Extraction?

Space resource extraction can be divided into two categories, depending on where an extracted space resource will be used. The first is *in-situ resource utilization* (ISRU), in which resources are extracted from a celestial body to be used for other in-space activities.[1] For instance, some proposed architectures to support lunar activity would use water extracted from the Moon to make fuel in support of future lunar operations.[2] The second is the extraction of resources from a celestial body and the transport of those resources to Earth to be used for commercial purposes. For example, mining asteroids for precious metals, such as platinum and rhodium, to sell on Earth falls within this category.

These two categories of space resource extraction may employ similar or related technologies and capabilities. Both activities would require, for instance, the ability to identify specific locations

[1] *Celestial body* is an astronomical term referring to an aggregation of matter in the universe—such as a planet, asteroid, moon, or star—that can be considered as a single unit. For more information on in-situ resource utilization (ISRU), see National Aeronautics and Space Administration (NASA), "Using Space-Based Resources for Deep Space Exploration," July 26, 2023, https://www.nasa.gov/overview-in-situ-resource-utilization/.

[2] Nicholas James Bennett, Damon Ellender, and Andrew G. Dempster, "Commercial Viability of Lunar In-Situ Resource Utilization (ISRU)," *Planetary and Space Science*, vol. 182 (March 2020), https://doi.org/10.1016/j.pss.2020.104842; Gerald Sanders, "In Situ Resource Utilization (ISRU) – Surface Excavation & Construction," presentation, NASA, January 21, 2021, https://www.nasa.gov/wp-content/uploads/2015/03/jsanders_lunar_isru_tagged_0.pdf.

that have resources of interest, extract those resources, and refine them into their preferred form. Some stakeholders view ISRU as enabling future extractive mining activities for terrestrial use.[3]

To date, U.S. extraction has been limited to samples for public benefit or use. As of July 2024, NASA and other space agencies have collected samples from several celestial bodies; these samples were collected on a small scale and used for either scientific or diplomatic purposes.[4] NASA and other space agencies have also conducted a few ISRU technology maturation or demonstration missions. Space agencies and commercial companies have not, to date, extracted space resources on a scale necessary to demonstrate the ability to support a commercially viable terrestrial business or support ISRU for in-space operations.

Stakeholders have proposed different possible architectures for space resource extraction. For example, to extract water to support exploration of the Moon, researchers at Texas A&M University proposed using autonomous rovers to collect materials on the surface and transport them to a central refining plant.[5] Researchers at NASA's Glenn Research Center and Johnson Space Center have proposed similar architectures to create fuel to enable transportation from the Moon to Mars.[6] A group of stakeholders convened by the California Institute of Technology's Jet Propulsion Laboratory proposed an architecture in which a spacecraft lands on a near-Earth asteroid to either collect a portion of or capture the entire asteroid. The asteroid or portion thereof could be transported to Earth or to an orbit near the Moon, where the resources of value could be extracted.[7]

Potential Space Resources of Interest

Space agencies, researchers, and companies have identified several resources that may be present on asteroids, the Moon, or Mars and viable candidates for extraction. The following are a few examples:

- **Oxygen** and **hydrogen** might be extracted from water ice found on the Moon's surface or from the atmosphere on Mars and, in turn, used for life support or to create rocket fuel.[8]
- **Iron, silicon,** and **aluminum** might be extracted from asteroids or the Moon's surface and used in space as construction materials for space exploration infrastructure.[9]
- **Platinum group metals** (PGMs)—such as platinum, rhodium, and iridium—might be extracted from asteroids or the Moon and transported to the Earth to sell.[10]
- **Lunar regolith**—or the fragments of rock material that covers the Moon's surface—might be collected, processed, and used as building material for lunar infrastructure, such as landing pads.[11]
- **Helium-3**, a rare isotope of helium that can be used in quantum computing and medical imaging applications, might be extracted from the Moon and used to create energy for space exploration or transported to the Earth to sell.[12]

---

[3] Luigi Scatteia and Yann Perrot, *Lunar Market Assessment: Market Trends and Challenges in the Development of a Lunar Economy*, PricewaterhouseCoopers (PWC) Research Paper, September 2021, p. 27, https://www.pwc.com.au/industry/space-industry/lunar-market-assessment-2021.pdf.

[8] David Kornuta et al., *Commercial Lunar Propellant Architecture: A Collaborative Study of Lunar Propellant Production*, March 2019, https://www.osti.gov/pages/servlets/purl/1503160; Jeffrey A. Hoffman et al., "Mars Oxygen ISRU Experiment (MOXIE)—Preparing for Human Mars Exploration," *Science Advances*, vol. 8, no. 25 (August 31, 2022), https://doi.org/10.1126/sciadv.abp8636.

[9] Gerald B. Sanders et al., "Lunar In-Situ Resource Utilization in the ISECG Human Lunar Exploration Reference Architecture," paper presented at the 61st International Astronautical Congress, Prague, Czech Republic, 2010, https://www.globalspaceexploration.org/wordpress/wp-content/uploads/IAC61/IAC-10.A5.1.7-Lunar-ISRU.pdf; Kevin M. Cannon, Matt Gialich, and Jose Acain, "Precious and Structural Metals on Asteroids," *Planetary and Space Science*, vol. 225 (2023), https://doi.org/10.1016/j.pss.2022.105608.

[10] Kevin M. Cannon, Matt Gialich, and Jose Acain, "Precious and Structural Metals on Asteroids," *Planetary and Space Science*, vol. 225 (2023), https://doi.org/10.1016/j.pss.2022.105608.

(continued...)

In-Situ Resource Utilization (ISRU)

ISRU refers to the extraction of space resources for use in space or on celestial bodies. Space agencies such as NASA hope to develop capabilities to extract and use resources from the Moon and Mars to enable sustained space exploration.[13]

Deep space exploration—particularly for long-duration crewed missions—will likely require significant amounts of rocket fuel, water, oxygen, and other resources. To escape Earth's gravitational pull and counter atmospheric drag, space launch requires a significant amount of rocket fuel, or *propellant.* The majority—often as much as 90%—of a rocket's mass is propellant. The relationship between the mass of the *payload*—what is to be transported into space—and the amount of propellant required is exponential; that is, even slight increases in the mass of a payload require a much larger increase in propellant and, in turn, increase the cost of the launch.[14] NASA and other space agencies hope that extracting supplies in space, rather than transporting them from Earth, may reduce costs and enable operations that may have otherwise been cost prohibitive.

Frequently discussed resources of interest for ISRU include oxygen, hydrogen, and water. Once extracted and processed, they may be used as fuel for spacecraft or in life support systems for

---

[7] John Brophy et al., *Asteroid Retrieval Feasibility Study*, Keck Institute for Space Studies, California Institute of Technology Jet Propulsion Laboratory, April 2, 2012, p. 48, https://kiss.caltech.edu/final_reports/Asteroid_final_report.pdf.

[8] David Kornuta et al., *Commercial Lunar Propellant Architecture: A Collaborative Study of Lunar Propellant Production*, March 2019, https://www.osti.gov/pages/servlets/purl/1503160; Jeffrey A. Hoffman et al., "Mars Oxygen ISRU Experiment (MOXIE)—Preparing for Human Mars Exploration," *Science Advances*, vol. 8, no. 25 (August 31, 2022), https://doi.org/10.1126/sciadv.abp8636.

[9] Gerald B. Sanders et al., "Lunar In-Situ Resource Utilization in the ISECG Human Lunar Exploration Reference Architecture," paper presented at the 61st International Astronautical Congress, Prague, Czech Republic, 2010, https://www.globalspaceexploration.org/wordpress/wp-content/uploads/IAC61/IAC-10.A5.1.7-Lunar-ISRU.pdf; Kevin M. Cannon, Matt Gialich, and Jose Acain, "Precious and Structural Metals on Asteroids," *Planetary and Space Science*, vol. 225 (2023), https://doi.org/10.1016/j.pss.2022.105608.

[10] Kevin M. Cannon, Matt Gialich, and Jose Acain, "Precious and Structural Metals on Asteroids," *Planetary and Space Science*, vol. 225 (2023), https://doi.org/10.1016/j.pss.2022.105608.

[11] Charun Bao et al., "Lunar *In Situ* Large-Scale Construction: Quantitative Evaluation of Regolith Solidification Techniques," *Engineering*, in press, March 24, 2024, https://doi.org/10.1016/j.eng.2024.03.004; Thomas J. Colvin et al., *Demand Drivers of the Lunar and Cislunar Economy*, Institute for Defense Analyses, Science and Technology Policy Institute (STPI), April 2020, pp. 50-51, https://www.ida.org/-/media/feature/publications/d/de/demand-drivers-of-the-lunar-and-cislunar-economy/d-13219.ashx.

[12] Eric Berger, "Mining Helium-3 on the Moon Has Been Talked About Forever—Now a Company Will Try," *ArsTechnica*, March 13, 2024, https://arstechnica.com/space/2024/03/mining-helium-3-on-the-moon-has-been-talked-about-forever-now-a-company-will-try/.

[13] NASA, *NASA's Lunar Exploration Program Overview*, September 2020, pp. 28-29, https://www.nasa.gov/wp-content/uploads/2020/12/artemis_plan-20200921.pdf; NASA, *NASA's Plan for Sustained Lunar Exploration and Development*, 2020, https://www.nasa.gov/wp-content/uploads/2020/08/a_sustained_lunar_presence_nspc_report4220final.pdf.

[14] Paul D. Spudis, "Lowering the Cost of Human Spaceflight," *Smithsonian Magazine*: *Air & Space*, September 12, 2016, https://www.smithsonianmag.com/air-space-magazine/lowering-cost-human-spaceflight-180960420/; Don Petit, "The Tyranny (and Power) of Rocket Travel," *Smithsonian Magazine*: *Air & Space*, May 2, 2012, https://www.smithsonianmag.com/air-space-magazine/the-tyranny-and-power-of-rocket-travel-78586310/.

astronauts.[15] Other proposed applications include the use of lunar regolith as a construction material.[16]

In preparation for NASA's planed Artemis lunar exploration missions, the agency and its partner space agencies have been particularly interested in ISRU on the Moon.[17] As NASA states in its 2020 *Lunar Exploration Program Overview*, "opportunities to harvest lunar resources could lead to safer, more efficient operations with less dependence on supplies delivered from Earth."[18]

Extracting Space Resources to Sell on Earth

Some companies—in the United States and other countries—are interested in extracting certain resources from the Moon or asteroids to sell on Earth. These companies say they intend to generate a profit by targeting high-value resources that either are challenging to access or exist in limited quantity on Earth.[19]

Extraction of resources in space by commercial entities may supplement limited terrestrial availability and meet projected demand for their use. Some researchers, for instance, anticipate that transitioning to clean energy technologies will require more production and use of metals such as copper, cobalt, and nickel and that extracting these metals from asteroids may help supply that transition.[20] Similarly, a spokesperson at Interlune—a company that plans to extract helium-3 on the Moon—posits that collective access to larger amounts of helium-3 may reduce the cost of

---

[15] Luigi Scatteia and Yann Perrot, *Lunar Market Assessment: Market Trends and Challenges in the Development of a Lunar Economy*, PWC Research Paper, September 2021, p. 27, https://www.pwc.com.au/industry/space-industry/lunar-market-assessment-2021.pdf.

[16] Juan-Carlos Ginés-Palomares, Miranda Fateri, and Eckehard Kalhöfer, "Laser Melting Manufacturing of Large Elements of Lunar Regolith Simulant for Paving on the Moon," *Scientific Reports*, vol. 13, no. 1 (October 12, 2023), https://doi.org/10.1038/s41598-023-42008-1.

[17] NASA, *NASA's Lunar Exploration Program Overview*, September 2020, pp. 28-29, https://www.nasa.gov/wp-content/uploads/2020/12/artemis_plan-20200921.pdf; NASA, *NASA's Plan for Sustained Lunar Exploration and Development*, 2020, https://www.nasa.gov/wp-content/uploads/2020/08/a_sustained_lunar_presence_nspc_report4220final.pdf; European Space Agency (ESA), "Off-Earth Manufacturing: Using Local Resources to Build a New Home," August, 17, 2023, https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Discovery_and_Preparation/Off-Earth_manufacturing_using_local_resources_to_build_a_new_home; Japan Aerospace Exploration Agency (JAXA), "Lunar Polar Exploration (LUPEX) Project Underway," press release, 2023, https://global.jaxa.jp/activity/pr/jaxas/no092/02.html.

[18] NASA, *NASA's Lunar Exploration Program Overview*, September 2020, p. 28, https://www.nasa.gov/wp-content/uploads/2020/12/artemis_plan-20200921.pdf.

[19] Ramin Skibba, "Things Are Looking Up for Asteroid Mining," *WIRED*, October 20, 2023, https://www.wired.com/story/things-are-looking-up-for-asteroid-mining/; Shriya Yarlagadda, "Economics of the Stars: The Future of Asteroid Mining and the Global Economy," *Harvard International Review*, April 8, 2022, https://hir.harvard.edu/economics-of-the-stars/; Andy Greenspan, "Precious Metals in Peril: Can Asteroid Mining Save Us?" *Special Edition: Dear Madam/Mister President* (blog), Harvard University's Graduate School of Arts and Sciences, October 25, 2016, https://sitn.hms.harvard.edu/flash/2016/precious-metals-peril-can-asteroid-mining-save-us/.

[20] Maxwell Fleming et al., "Mining in Space Could Spur Sustainable Growth," *Earth, Atmospheric, and Planetary Sciences*, vol. 120, no. 43 (October 24, 2023), https://doi.org/10.1073/pnas.2221345120; Ramin Skibba, "Things Are Looking Up for Asteroid Mining," *WIRED*, October 20, 2023, https://www.wired.com/story/things-are-looking-up-for-asteroid-mining/.

the isotope, in turn enabling new applications.[21] Some proponents believe that space resources may also be a strategic alternative to importing those same resources from other countries.[22]

What Are the Existing U.S. Efforts in Space Resource Extraction?

This section provides an overview of U.S. government and commercial efforts in space resource extraction. NASA is focusing primarily on ISRU for potential use in future agency missions, such as by extracting water on the Moon. Examples of private-sector efforts include projects to extract platinum group metals from asteroids and to extract helium-3 from the Moon.

National Aeronautics and Space Administration

NASA intends to develop ISRU capabilities as part of its long-term exploration goals.[23] NASA predicts that by extracting resources from space, rather than launching them from Earth, the agency can reduce transportation costs and enable sustained presence on the Moon and Mars.[24] In its strategic plan for sustained lunar exploration, NASA describes ISRU as a technology "in early development for significant long-term benefits."[25] NASA is supporting R&D on ISRU for future missions on the Moon and Mars through several programs and planetary science missions described below. NASA has also entered into contracts with four companies to extract resources from the Moon and transfer ownership to the agency, also described below.

Space Technology Development and Maturation

NASA's Space Technology Mission Directorate (STMD) identified ISRU as a key capability area in its 2022 strategic framework for NASA technology development, which is used to guide the directorate's investments.[26] STMD has several technology development and maturation programs that support the development of ISRU, among other technologies.

The STMD Lunar Surface Innovation Initiative (LSII) aims to support technology development for the Artemis program, including ISRU-related R&D, through collaboration with academia, the private sector, and other U.S. government agencies. LSII includes the Lunar Surface Innovation Consortium, which is a nationwide alliance of universities, industry, nonprofits, and U.S.

---

[21] Eric Berger, "Mining Helium-3 on the Moon Has Been Talked About Forever—Now a Company Will Try," *ArsTechnica*, March 13, 2024, https://arstechnica.com/space/2024/03/mining-helium-3-on-the-moon-has-been-talked-about-forever-now-a-company-will-try/.

[22] Testimony of Lang Eric Sundby, in U.S. Congress, House Committee on Natural Resources, Subcommittee on Oversight and Investigations, *The Mineral Supply Chain and the New Space Race*, hearings, 118th Cong., 1st sess., December 12, 2023, https://naturalresources.house.gov/uploadedfiles/testimony_sundby.pdf; Testimony of Greg Autry, PhD, in U.S. Congress, House Committee on Natural Resources, Subcommittee on Oversight and Investigations, *The Mineral Supply Chain and the New Space Race*, hearings, 118th Cong., 1st sess., December 12, 2023, https://naturalresources.house.gov/uploadedfiles/testimony_autry.pdf.

[23] NASA, *NASA's Plan for Sustained Lunar Exploration and Development*, 2020, https://www.nasa.gov/wp-content/uploads/2020/08/a_sustained_lunar_presence_nspc_report4220final.pdf?emrc=5aa8ef.

[24] Ibid., pp. 8-12.

[25] Ibid., p. 12.

[26] NASA Science Technology Mission Directorate (STMD), *Strategic Framework: Charting the Horizon of NASA Technology Development*, 2022, https://techport.nasa.gov/strategy.

government agencies focused on developing technologies to support a sustained presence on the Moon.[27]

STMD has several extramural grant programs that have supported projects related to ISRU. Following are a few of these grant programs:

- The NASA Innovative Advanced Concepts (NIAC) program funds early-stage technology concept studies for "visionary ideas that could transform future NASA missions."[28] For instance, NASA awarded a NIAC grant of $175,000 in 2023 to the company Lunar Resources, Inc., to conduct a study on a potential pipeline to transport oxygen extracted on the Moon to another location on the lunar surface.[29]
- The Game Changing Development (GCD) program focuses on advancing "exploratory concepts" to prototypes.[30] One relevant project funded by GCD is the Polar Resources Ice Mining Experiment-1 (PRIME-1), which is intended to be the first ISRU demonstration on the Moon and is planned for launch under the CLPS program.[31] PRIME-1 is a suite of instruments for assessing water content on the Moon's south pole.[32]
- The Space Technology Research Grants (STRG) program supports academic researchers in accelerating the development of early-concept space technologies that may support the goals of NASA, other U.S. government agencies, and the commercial space sector.[33] One of STRG's program elements—Lunar Surface Technology Research (LuSTR)—focuses on technologies that support Artemis missions in alignment with the LSII focus areas.[34] An example of its ISRU-related grants is a 2023 award to the Colorado School of Mines to research a potential process for extracting oxygen and metals from the Moon.[35]

[27] NASA, "Lunar Surface Innovation Initiative," January 19, 2024, https://www.nasa.gov/space-technology-mission-directorate/lunar-surface-innovation-initiative/.

[28] NASA, "NASA Innovative Advanced Concepts," March 15, 2024, https://www.nasa.gov/stmd-the-nasa-innovative-advanced-concepts-niac/.

[29] NASA, "NIAC 2023 Phase I and Phase II Selections," January 9, 2023, https://www.nasa.gov/general/niac-2023-phase-i-and-phase-ii-selections/; Loura Hall, "Lunar South Pole Oxygen Pipeline," NASA, January 9, 2023, https://www.nasa.gov/general/lunar-south-pole-oxygen-pipeline/.

[30] NASA, "About GCD," March 4, 2024, https://www.nasa.gov/about-gcd/.

[31] NASA selected the Commercial Lunar Payload Services (CLPS) provider Intuitive Machines to transport the Polar Resources Ice Mining Experiment-1 (PRIME-1) to the Moon. This mission is scheduled for launch in 2024. NASA, "Commercial Lunar Payload Services," June 15, 2023, https://www.nasa.gov/reference/commercial-lunar-payload-services/.

[32] NASA, *Congressional Budget Request for Fiscal Year 2025*, 2024, p. ST-14, https://www.nasa.gov/fy-2025-budget-request/; NASA, "Polar Resources Ice Mining Experiment-1 (PRIME-1)," April 19, 2024, https://www.nasa.gov/polar-resources-ice-mining-experiment-1/.

[33] NASA, "Space Technology Research Grants," July 27, 2023, https://www.nasa.gov/space-technology-research-grants/.

[34] NASA, "Lunar Surface Technology Research (LuSTR)," October 5, 2023, https://www.nasa.gov/lunar-surface-technology-research-lustr/.

[35] Loura Hall, "MAGMA: Molten Aluminum Generation for Manufacturing Additively," September 12, 2023, https://www.nasa.gov/general/magma-molten-aluminum-generation-for-manufacturing-additively/.

Volatiles Investigating Polar Exploration Rover

In July 2024, NASA decided to discontinue the development of one related project, the Volatiles Investigating Polar Exploration Rover (VIPER).[36] Until its cancellation, VIPER had been scheduled for launch in September 2025 through the Commercial Lunar Payload Services (CLPS) program. After a comprehensive internal review, NASA announced its intent to discontinue the VIPER project, citing "cost increases, delays to the launch data, and risks of future cost growth." The agency noted that continuing VIPER "would result in an increased cost" that may cause "cancellation or disruption to other CLPS missions."[37]

The intent of VIPER was to better understand the amount and distribution of water ice on the Moon and would have included several instruments designed to study and map water ice deposits.[38] If successful, VIPER would have been the first resource-mapping mission in space, and NASA had intended to use the data collected to determine a landing site for Artemis III.[39]

The estimated total cost of this mission was $505 million, as of January 2024.[40] NASA intends to repurpose VIPER's instruments and components for future missions, and the agency will also consider proposals from U.S. industry and international partners to use the VIPER system at no cost to the government. The cancellation of this mission has been controversial.[41]

The agency intends to "pursue alternative methods" to accomplish VIPER's goals and to "verify the presence of ice" at sites of interest.[42] In its announcement, NASA identified three efforts that it hopes may fulfill VIPER's objectives: PRIME-1, which is discussed in the previous subsection; the Lunar Terrain Vehicle, a rover to enable crewed exploration of the Moon's surface, including sample return campaigns; and future unspecified missions that may include repurposed VIPER instruments.[43]

Asteroid Research Missions

NASA has several planetary science missions—completed, ongoing, and planned—with the goal of studying asteroids. Nearly all of these missions have been, or are planned to be, flybys, where a spacecraft approaches an asteroid to collect data but does not land on its surface. NASA does not have plans to extract resources from asteroids, aside from samples for research purposes. These missions, however, may inform future efforts to extract space resources by providing data on the composition of asteroids and fostering the development of relevant technologies.

---

[36] Tiernan P. Doyle, "NASA Ends VIPER Project, Continues Moon Exploration," NASA, press release, July 17, 2024, https://www.nasa.gov/news-release/nasa-ends-viper-project-continues-moon-exploration/. This mission built on the Resource Prospector rover that NASA cancelled in 2018 during early development stages.

[37] Ibid.

[38] The surface temperatures on parts of the Moon, such as its poles, are low (below -170° Celsius), and as a result, water found in those regions is frozen.

[39] NASA, *Congressional Budget Justification for Fiscal Year 2025*, 2024, p. PS-31, https://www.nasa.gov/fy-2025-budget-request/.

[40] GAO, *NASA: Assessments of Major Projects*, GAO-24-106767, June 2024, p. 59, https://www.gao.gov/assets/gao-24-106767.pdf.

[41] Casey Dreier, "For Parts: Lunar Rover, Never Used," *Planetary Society*, July 23, 2024, https://www.planetary.org/articles/nasa-cancels-viper.

[42] Tiernan P. Doyle, "NASA Ends VIPER Project, Continues Moon Exploration," NASA, press release, July 17, 2024, https://www.nasa.gov/news-release/nasa-ends-viper-project-continues-moon-exploration/.

[43] Ibid.

In 2023, NASA completed the only U.S. mission to date to collect a physical sample from an asteroid: the Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-REx) mission. The overall goal of both the original and a subsequent OSIRIS mission is to better understand the formation of the solar system and origins of life;[44] in the processing of conducting this research, the data collected and technologies used may inform efforts by others working on resource extraction from asteroids.

The OSIRIS-REx spacecraft was launched in 2016 and traveled to the asteroid Bennu, landing on and collecting a sample from the asteroid's surface in 2020. In September 2023, the OSIRIS-REx spacecraft delivered a capsule containing a sample of asteroid material—about 0.1 kilograms—from Bennu back to Earth. To date, this is the largest sample of an asteroid ever collected in space.[45] According to data compiled by The Planetary Society, the total cost to date, adjusted for inflation, of the OSIRIS-REx mission is $1.3 billion.[46]

Following the delivery of the sample capsule, NASA has since diverted this same spacecraft to the near-Earth asteroid Apophis. OSIRIS-REx is expected to study the asteroid from orbit under the new mission name OSIRIS-Apophis Explorer (OSIRIS-APEX).

Existing Contracts with Commercial Entities

In 2020, NASA entered into contracts with four companies to collect resources from the Moon and to transfer ownership of those resources to NASA. Two of these companies—Lunar Outpost of Colorado and Masten Space Systems[47] of California—are U.S. based, while the other two—ispace Japan and ispace Europe—are based in Japan and Luxembourg, respectively.[48] The total value of these four contracts, considered to be a nominal amount, was $25,001:[49] 10% was paid upon award, 10% is to be paid upon launch, and the remaining 80% is to be paid upon successful completion. The value of each contract varies, ranging from $15,000 to a single dollar.[50] As of the date of this report, these companies have not completed a qualifying mission.

Then-NASA Associate Administrator Mike Gold described these contracts as setting an "important policy and precedent," emphasizing that NASA by awarding these contracts hoped to

[44] NASA, "OSIRIS-REx In Depth," February 2024, https://science.nasa.gov/mission/osiris-rex/in-depth/.

[45] Rachel Barry, "NASA Announces OSIRIS-REx Bulk Sample Mass," NASA, February 15, 2024, https://blogs.nasa.gov/osiris-rex/2024/02/15/nasa-announces-osiris-rex-bulk-sample-mass/.

[46] The Planetary Society, "Cost of OSIRIS-REx," 2024, https://www.planetary.org/space-policy/cost-of-osiris-rex; The Planetary Society, "OSIRIS-REx" tab within "Planetary Exploration Budget Dataset – The Planetary Society," (dataset), accessed July 11, 2024, https://docs.google.com/spreadsheets/d/12frTU01gfT1CXGWFimN3whf4348F_r3XolTqBt02OyM/edit?gid=857538289#gid=857538289.

[47] In 2022, Masten Space Systems filed for bankruptcy, and most of its assets were sold to another space company, Astrobotic. Jeff Foust, "Court Approves Sale of Masten Assets to Astrobotic," *SpaceNews*, September 11, 2022, https://spacenews.com/court-approves-sale-of-masten-assets-to-astrobotic/.

[48] NASA, "NASA Selects Companies to Collect Lunar Resources for Artemis Demonstrations," press release, December 3, 2020, https://www.nasa.gov/news-release/nasa-selects-companies-to-collect-lunar-resources-for-artemis-demonstrations/; Jackie Wattles, "NASA Is Paying Startups for Moon Rocks. It's not What You Think," *CNNBusiness*, December 4, 2020, https://www.cnn.com/2020/12/04/tech/nasa-moon-resource-mining-artemis-scn/index.html.

[49] According to one expert, "the innovation here is not of financial value but of creating business and legal norms," perhaps explaining the low dollar value of these contracts. See Justin Harper, "NASA to Pay Company $1 to Collect Rocks from Moon," *BBC*, December 4, 2020, https://www.bbc.com/news/business-55170788.

[50] NASA, "NASA Selects Companies to Collect Lunar Resources for Artemis Demonstrations," press release, December 3, 2020, https://www.nasa.gov/news-release/nasa-selects-companies-to-collect-lunar-resources-for-artemis-demonstrations/.

"demonstrate explicitly that you can extract and you can utilize [space] resources."[51] Then-NASA Administrator Jim Bridenstine stated that by awarding these contracts, NASA seeks to "make sure that there is a norm of behavior that says that resources can be extracted and that we're doing it in a way that is in compliance with the Outer Space Treaty."[52]

In a 2022 meeting of the UN Committee on the Peaceful Uses of Outer Space's (COPUOS's) Legal Subcommittee, the U.S. Head of the Delegation described this NASA effort as "an opportunity to begin working through practical issues in space resources."[53]

U.S. Geological Survey

The USGS, within the Department of the Interior (DOI), collects and provides scientific information to support the management of natural resources (e.g., water, energy, minerals, ecosystems) and to mitigate natural hazard risks.[54] USGS's early responsibilities, as described in statute, include "the classification of public lands and examination of the geological structure, mineral resources, and products of the national domain."[55] In 1962, Congress extended those responsibilities to include resources "outside the national domain where determined by the Secretary [of the Interior] to be in the national interest," that is, USGS responsibilities could extend beyond the borders of the United States.[56] In 2015, USGS management interpreted this extension to apply to space.[57]

USGS's Astrogeology Science Center conducts research in planetary geology and creates maps of celestial bodies. This center was founded in 1963 to map the Moon and support the training of NASA's Apollo astronauts.[58] USGS has published studies analyzing the resources on asteroids and the Moon.[59] In collaboration with NASA, USGS hosted a workshop in 2023 on gaps in observation and capabilities that inhibit space resource detection and assessment, and technology needed to help meet the goals of NASA's Artemis efforts.[60]

---

[51] Michael Sheetz, "NASA Will Pay a Company $1 to Collect Moon Rocks," *CNBC*, December 3, 2020, https://www.cnbc.com/2020/12/03/nasa-will-pay-a-company-1-to-collect-moon-rocks.html; Jeff Foust, "NASA Selects Four Companies for Lunar Sample Purchases," *SpaceNews*, December 3, 2020, https://spacenews.com/nasa-selects-four-companies-for-lunar-sample-purchases/.

[52] Jim Bridenstine, keynote address at the 2nd Summit for Space Sustainability, September 10, 2020, https://swfound.org/media/207210/bridenstine-keynote.pdf.

[53] U.S. Mission to International Organizations in Vienna, "61st Session of the COPUOS Legal Subcommittee – Agenda Item 15: Potential Legal Models for Activities in Exploration, Exploitation and Utilization of Space Resources," statement to the UN Committee on the Peaceful Uses of Outer Space (COPUOS) Legal Subcommittee, March 28, 2022, https://vienna.usmission.gov/2022-copuos-lsc-u-s-on-space-resources/.

[54] For more information, see CRS In Focus IF12358, *The U.S. Geological Survey (USGS): Background and FY2024 Appropriations*, by Anna E. Normand, and CRS Report R45480, *U.S. Department of the Interior: An Overview*, by Mark K. DeSantis.

[55] 43 U.S.C. §31(a).

[56] P.L. 87-626; 43 U.S.C. §31(b).

[57] Laszlo Keszthelyi et al., *Feasibility Study for the Quantitative Assessment of Mineral Resources in Asteroids*, USGS Open-File Report 2017-1041, 2017, pp. 1-2, https://pubs.usgs.gov/of/2017/1041/ofr20171041.pdf.

[58] USGS, "Astrogeology Science Center: About," https://www.usgs.gov/centers/astrogeology-science-center/about.

[59] Ibid.; Laszlo P. Keszthelyi et al., *Assessment of Lunar Resource Exploration in 2022*, Circular 1507, U.S. Geological Survey, 2023, https://pubs.usgs.gov/circ/1507/cir1507.pdf.

[60] USGS, "Workshop Agenda – Technologies to Fill Observation & Capability Gaps for the Off-World Mineral Resource Economy," 2023, https://www.usgs.gov/centers/national-innovation-center/workshop-agenda-technologies-fill-observation-capability-gaps.

Defense Advanced Research Projects Agency

DARPA is an agency within the Department of Defense (DOD) responsible for catalyzing the development of technologies for national security.[61] In 2023, DARPA announced the initiation of its 10-Year Lunar Architecture (LunA-10) capability study.[62] The LunA-10 capability study aims to develop a "series of shareable, scalable systems that interoperate" in order to support sustained presence on the Moon.[63]

ISRU is one of the LunA-10 focus areas. DARPA selected 14 companies to participate in the LunA-10 study,[64] with Cislunar Industries, Helios, Icon, and Sierra Space conducting studies on different technologies and architectures for ISRU.[65] DARPA offered awards of up to $1 million to the selected companies. These companies presented their work at the April 2024 meeting of NASA's Lunar Surface Innovation Consortium and were instructed to provide a final report in June 2024.[66]

U.S. Commercial Interest

Several private U.S. companies hope to develop space resource extraction capabilities. Such companies may focus entirely on space resource extraction, or they may offer other, unrelated services or products. These companies view the Moon, asteroids, or both as potential sites for extraction and consider their potential customers to be space agencies or companies on Earth. Some space resource companies view governments and their space agencies as their main potential customers and hope to eventually expand their customer base to private industry as their technologies mature.[67] Such companies plan to either sell space resources, use space resources to construct infrastructure, or offer related services.

Examples of companies that hope to extract and sell space resources are AstroForge, which plans to extract platinum-group metals from asteroids, and Interlune, which plans to extract helium-3

---

[61] For more information on the Defense Advanced Research Projects Agency (DARPA), see CRS Report R45088, *Defense Advanced Research Projects Agency: Overview and Issues for Congress*, by Marcy E. Gallo.

[62] DARPA, "A Framework for Optimized, Integrated Lunar Infrastructure," press release, August 15, 2023, https://www.darpa.mil//news-events/2023-08-15.

[63] Ibid.

[64] Jeff Foust, "DARPA Picks 14 Companies for Lunar Architecture Study," *SpaceNews*, December 6, 2023, https://spacenews.com/darpa-picks-14-companies-for-lunar-architecture-study/.

[65] DARPA, "LunA-10 Capability Study LSIC April 2024 Performer Initial Results," slideshow presentation at the Lunar Surface Innovation Consortium (LSIC) 2024 Spring Meeting, Laurel, MD, April 2024, https://www.darpa.mil/attachments/LunA-10%20Capability%20Study_LSIC%20April%202024_Performer%20Initial%20Results%20Decks2.pdf.

[66] As of July 2024, a public report was not available.

[67] Mathias Link, Gary Martin, and Joseph Mousel, "The Economics of Space Resources: Future Markets and Value Chains," in *Handbook of Space Resources*, ed. Viorel Badescu, Kris Zacny, and Yoseph Bar-Cohen (Cham, Switzerland: Springer, 2023), p. 1037, https://doi.org/10.1007/978-3-030-97913-3_31; Luigi Scatteia and Yann Perrot, *Lunar Market Assessment: Market Trends and Challenges in the Development of a Lunar Economy*, PWC Research Paper, September 2021, p. 27, https://www.pwc.com.au/industry/space-industry/lunar-market-assessment-2021.pdf.

from the Moon.[68] AstroForge reportedly raised $13 million in funding as of December 2023, and Interlune has raised $18 million in seed capital as of January 2023.[69]

Other companies, such as ICON and Redwire Corporation, are developing technology to enable construction on the Moon using ISRU. These companies intend to use resources on the Moon as building materials for lunar infrastructure, such as landing pads. NASA has awarded grants to both ICON and Redwire to support the development of these technologies.[70]

Other companies aim to offer services that enable space resource extraction, such as prospecting or transporting extracted resources on the Moon. Lunar Outpost, for instance, is developing rovers to map and provide data on resources available on the Moon. In 2023, Lunar Outpost raised $12 million in funding.[71]

A few companies developing space resource extraction capabilities have filed for bankruptcy, been acquired by other companies, or are now dormant. For instance, Deep Space Industries and Planetary Resources—which raised a combined total of nearly $55 million[72] in private investments in the late 2010s—were unable to generate a profit and were subsequently acquired by companies who repurposed their technology for other applications.[73] Masten Space Systems—a company that, among other activities, intended to extract water from the Moon—filed for bankruptcy in 2022.[74]

A few non-space companies also participate in government-led R&D for space resource extraction and invest in companies developing these capabilities.[75] For instance, Caterpillar Inc.—an American construction, mining, and engineering equipment manufacturer—has participated in several NASA research and technology development programs relating to space resource extraction and was a sponsor for the commercial Astrobotic lunar lander.[76]

---

[68] Ramin Skibba, "Things Are Looking Up for Asteroid Mining," *WIRED*, October 20, 2023, https://www.wired.com/story/things-are-looking-up-for-asteroid-mining/; Jeff Foust, "Asteroid Mining Startup AstroForge to Launch First Missions This Year," *SpaceNews*, January 30, 2023, https://spacenews.com/asteroid-mining-startup-astroforge-to-launch-first-missions-this-year-2/.

[69] Jacob Lorinc, "The Dream of Space Mining Is Still an Expensive Challenge," *Bloomberg*, December 6, 2023, https://www.bloomberg.com/news/newsletters/2023-12-06/mining-rare-earths-and-metals-from-asteroids-is-an-expensive-challenge; Interlune, "Space Resources Startup Interlune Raises $18 Million in Seed Capital," press release, March 13, 2024, https://www.interlune.space/press-release/space-resources-startup-interlune-raises-18-million-in-seed-capital.

[70] Beth Ridgeway, "NASA, ICON Advance Lunar Construction Technology for Moon Missions," NASA, press release, November 29, 2022, https://www.nasa.gov/centers-and-facilities/marshall/nasa-icon-advance-lunar-construction-technology-for-moon-missions/; Loura Hall, "2023 NASA Tipping Point Selections," NASA, press release, July 24, 2023, https://www.nasa.gov/general/2023-nasa-tipping-point-selections/.

[71] Jacob Lorinc, "The Dream of Space Mining Is Still an Expensive Challenge," *Bloomberg*, December 6, 2023, https://www.bloomberg.com/news/newsletters/2023-12-06/mining-rare-earths-and-metals-from-asteroids-is-an-expensive-challenge.

[72] This amount is provided in FY2019 dollars and has not been adjusted for inflation.

[73] Atossa Araxia Abrahamian, "How the Asteroid-Mining Bubble Burst," *MIT Technology Review*, June 26, 2019, https://www.technologyreview.com/2019/06/26/134510/asteroid-mining-bubble-burst-history/.

[74] Jeff Foust, "Court Approves Sale of Masten Assets to Astrobotic," *SpaceNews*, September 11, 2022, https://spacenews.com/court-approves-sale-of-masten-assets-to-astrobotic/.

[75] Luigi Scatteia and Yann Perrot, *Lunar Market Assessment: Market Trends and Challenges in the Development of a Lunar Economy*, PWC Research Paper, September 2021, pp. 7-8, https://www.pwc.com.au/industry/space-industry/lunar-market-assessment-2021.pdf.

[76] Rachel Wallace, "There's a Cat® Logo on the Lunar Lander. Here's Why ... " Caterpillar, press release, January 8, 2024, https://www.cat.com/en_US/blog/nasa-using-caterpillar-technology.html; Bob Woods, "Caterpillar's (continued...)

Is Space Resource Extraction Allowed?

Disagreement persists over whether or not public or private space resource extraction is permissible. Per the Space Resource Exploration and Utilization Act of 2015 (P.L. 114-90, Title IV; codified at 51 U.S.C. §§51301 et seq.), U.S. entities engaged in commercial space resource extraction are entitled to the resource obtained, in accordance with applicable law, including the United States' obligations under international law. Not all observers agree, however, as to whether public or private space resource extraction is permitted under international law.[77] Some note that a perceived lack of entitlement certainty may deter financial investment in space resource extraction.[78]

This section provides an overview of the framework in U.S. statute, international agreements, and treaties and highlights some of the discussions of those frameworks.

Domestic Framework

The Space Resource Exploration and Utilization Act of 2015 states that U.S. commercial entities are entitled to any space resources they obtain.[79] This entitlement includes the right to "possess, own, transport, use, and sell" the resources they extract "in accordance with applicable law, including the international obligations of the United States."

This law directs the executive branch to discourage government barriers to commercial exploration and resource recovery and to facilitate and promote "commercial recovery of space resources," including through promoting the "right of United States citizens to engage in commercial exploration for and commercial recovery of space resources free from harmful interference."[80] Further, the law directed the President to submit a report to Congress on "commercial exploration for and commercial recovery of space resources." The law required this report to address the authorities needed to fulfill U.S. international obligations, including authorization and continuing supervision by the federal government and recommendations for responsibilities among federal agencies to address those authorities. In April 2016, the White House Office of Science and Technology Policy delivered this report to Congress.[81]

Autonomous Vehicles May Be Used by NASA to Mine the Moon and Build a Lunar Base," *CNBC*, October 23, 2019, https://www.cnbc.com/2019/10/23/caterpillar-and-nasa-developing-autonomous-vehicles-to-mine-the-moon.html.

[77] Philip De Man, "Exclusive Use in an Inclusive Environment: The Meaning of the Non-Appropriation Principle for Space Resource Exploitation," in *Space Regulation Library*, vol. 9, ed. Ram S. Jakhu (Cham, Switzerland: Springer, July 2016), p. xxvii, https://doi.org/10.1007/978-3-319-38752-9; Ricky J. Lee, "Law and Regulation of Commercial Mining of Minerals in Outer Space," in *Space Regulation Library*, vol. 7, ed. Ram S. Jakhu (Dordrecht, Germany: Springer, 2014), p. 320, https://doi.org/10.1007/978-94-007-2039-8; Testimony of Michelle Hanlon, in U.S. Congress, House Committee on Natural Resources, Subcommittee on Oversight and Investigations, *The Mineral Supply Chain and the New Space Race*, hearings, 118th Cong., 1st sess., December 12, 2023, https://naturalresources.house.gov/uploadedfiles/testimony_hanlon.pdf.

[78] Ricky J. Lee, "Law and Regulation of Commercial Mining of Minerals in Outer Space," in *Space Regulation Library*, vol. 7, ed. Ram S. Jakhu (Dordrecht, Germany: Springer, 2014), p. 320, https://doi.org/10.1007/978-94-007-2039-8; Yannick Radi, "Space Mining in Practice—An International Space Law Perspective on Upcoming Challenges," *European Society of International Law*, vol. 13, no. 8 (May 6, 2024), https://esil-sedi.eu/wp-content/uploads/2024/05/Radi-Vol.13-Issue-8_final.pdf; Katie Mak, "Space Arbitration: Protecting Space Investments," *Space Arbitration*, 2022, https://space-arbitration.com/space-arbitration-protecting-space-investments/.

[79] 51 U.S.C. §51303.

[80] 51 U.S.C. §51302.

[81] Letter from John P. Holden, then-Director of the White House Office of Science and Technology Policy, to Senator John Thune and Representative Lamar Smith, April 4, 2016, https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/csla_report_4-4-16_final.pdf.

Executive Order 13914, issued in April 2020 by President Trump, directed the Department of State, Department of Commerce, and NASA to take appropriate actions to encourage international support for "public and private recovery and use of resources in outer space."[82]

The Space Resource Exploration and Utilization Act of 2015 does not address which agency has regulatory or oversight authority for commercial space resource extraction. Current legislative and executive branch proposals to assign regulatory authority for in-space commercial activities not currently regulated—referred to as "on-orbit authority" or "mission authorization"—may address space resource extraction, if enacted. For more information, see the section below titled "Potential Gaps in Regulatory Oversight."

International Framework

At least three international governance frameworks—the Outer Space Treaty, the Artemis Accords, and the Moon Agreement—are directly relevant to space resource extraction.[83]

The Outer Space Treaty

The 1967 Outer Space Treaty is the foundational treaty governing space activities, with over 100 parties, including the United States.[84] Articles I and II of the Outer Space Treaty pertain to space resource use. Article I establishes that outer space, including the Moon and other celestial bodies, are to be free for exploration and use by all countries, and Article II states that space is "not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means."

The Outer Space Treaty forbids *national appropriation*, which some observers consider to be "irreconcilable with the extraction and exploitation of mineral resources from the surface or subsurface of celestial bodies, as these activities are deemed to either require or inevitably result in the creation of property rights, merely by virtue of their completion."[85] In such arguments, scholars note that in order to extract resources, one must have "some degree of exclusionary right in the area of [the] asteroid [or other celestial body] being mined, a right that would be contrary to those legal principles. Further, the act of extraction itself may contravene, by its very nature, the principle of non-appropriation."[86]

Others reject that interpretation of the Outer Space Treaty. Some scholars argue that national appropriation amounts only to "a narrow ban on actual claims of sovereignty, allowing an (albeit undefined) degree of ownership in extracted resources."[87] Others contend that it is unclear

[82] Executive Order 13914, "Encouraging International Support for the Recovery and Use of Space Resources," 85 *Federal Register* 20381, April 10, 2020, https://www.govinfo.gov/content/pkg/FR-2020-04-10/pdf/2020-07800.pdf.

[83] For more information, see Melissa de Swart, Stacey Henderson, and Michelle Neumann, "Space Resource Activities and the Evolution of International Space Law," *Acta Astronautica*, vol. 211 (October 2023), https://doi.org/10.1016/j.actaastro.2023.06.009.

[84] UN General Assembly, "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies," Resolution 2222, A/RES/2222(XXI), December 1, 1966, https://treaties.un.org/Pages/showDetails.aspx?objid=0800000280128cbd&clang=_en.

[85] Philip De Man, "Exclusive Use in an Inclusive Environment: The Meaning of the Non-Appropriation Principle for Space Resource Exploitation," in *Space Regulation Library*, vol. 9, ed. Ram S. Jakhu (Cham, Switzerland: Springer, July 2016), p. xxvii, https://doi.org/10.1007/978-3-319-38752-9.

[86] Ricky J. Lee, "Law and Regulation of Commercial Mining of Minerals in Outer Space," in *Space Regulation Library*, vol. 7, ed. Ram S. Jakhu (Dordrecht, Germany: Springer, 2014), https://doi.org/10.1007/978-94-007-2039-8.

[87] John G. Wrench, "Non-Appropriation, No Problem: The Outer Space Treaty Is Ready for Asteroid Mining," *Case* (continued...)

whether the prohibition on national appropriation applies to private entities.[88] Section 403 of the Space Resource Exploration and Utilization Act of 2015 includes that "it is the sense of Congress that by the enactment of this Act, the United States does not thereby assert sovereignty or sovereign or exclusive rights or jurisdiction over, or the ownership of, any celestial body." The Artemis Accords (see the next section) provide the position of the signatories that "the extraction of space resources does not inherently constitute national appropriation under Article II of the Outer Space Treaty."[89]

In a 2023 hearing of the House Committee on Natural Resources, Subcommittee on Oversight and Investigations, the executive director of the University of Mississippi Center for Air and Space Law, Michelle Hanlon, argued that given the gray areas of international law, "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. ... The bottom line is that there are gaps in the law which may be filled by the first mover."[90] In this context, the United States might establish a first-mover advantage by both conducting space resource extraction and by creating frameworks to monitor commercial activities—either internally or in collaboration with its allies. Should other countries adopt practices set by the United States, those practices may become customary international law, which refers to international obligations formed by consistent practices of countries forming a sense of legal obligation.[91] Conversely, some scholars and policy researchers recommend that the United States instead promote the creation of a new space treaty or seek to amend the Outer Space Treaty to explicitly address space resource extraction.[92]

The Space Resource Exploration and Utilization Act requires commercial entities to obtain resources in accordance with U.S. international obligations, which some scholars note "may very well pose difficulties considering the current state of international space law."[93]

The Artemis Accords

The Artemis Accords, initiated in 2020, are a U.S.-led series of nonbinding pacts that establish a set of principles and guidelines for space exploration.[94] The principles in these accords are

---

Western Reserve Journal of International Law, vol. 51, no. 1 (2019), p. 439, https://scholarlycommons.law.case.edu/cgi/viewcontent.cgi?article=2546&context=jil.

[88] Laura C. Byrd, "Soft Law in Space: A Legal Framework for Extraterrestrial Mining," *Emory Law Journal*, vol. 71, no. 4 (2022), p. 814, https://scholarlycommons.law.emory.edu/cgi/viewcontent.cgi?article=1454&context=elj.

[89] NASA and the U.S. Department of State, "Artemis Accords: Principles for Cooperation in the Civil Exploration and Use of the Moon, Mars, Comets, and Asteroids for Peaceful Purposes," October 13, 2020, p. 4, https://www.nasa.gov/wp-content/uploads/2022/11/Artemis-Accords-signed-13Oct2020.pdf.

[90] Testimony of Michelle Hanlon, in U.S. Congress, House Committee on Natural Resources, Subcommittee on Oversight and Investigations, *The Mineral Supply Chain and the New Space Race*, hearings, 118th Cong., 1st sess., December 12, 2023, https://naturalresources.house.gov/uploadedfiles/testimony_hanlon.pdf.

[91] For more information, see CRS Report RL32528, *International Law and Agreements: Their Effect upon U.S. Law*, by Steve P. Mulligan.

[92] Todd Skauge, "Space Mining & Exploration: Facing a Pivotal Moment," *The Journal of Corporation Law*, vol. 45, no. 3 (August 2021), https://jcl.law.uiowa.edu/sites/jcl.law.uiowa.edu/files/2021-08/Skauge_Final_Web.pdf; Douglas Ligor, "Reduce Friction in Space by Amending the 1967 Outer Space Treaty," *War on the Rocks*, August 26, 2022, https://warontherocks.com/2022/08/stabilize-friction-points-in-space-by-amending-the-1967-outer-space-treaty/.

[93] Philip De Man, "Exclusive Use in an Inclusive Environment: The Meaning of the Non-Appropriation Principle for Space Resource Exploitation," in *Space Regulation Library*, vol. 9, ed. Ram S. Jakhu (Cham, Switzerland: Springer, July 2016), p. xxv, https://doi.org/10.1007/978-3-319-38752-9.

[94] The Artemis Accords are bilateral instruments with identical terms. NASA and the U.S. Department of State, (continued...)

intended to apply to civil space activities conducted by the civil space agencies of each signatory. Section 10 of the Artemis Accords directs signatories to extract and utilize space resources in a manner that complies with the Outer Space Treaty.[95] It also commits the signatories to informing the United Nations, the public, and the international scientific community about their space resource extraction activities and expresses the intent of the signatories to "contribute to multilateral efforts to further develop international practices and rules applicable to the extraction and utilization of space resources," including through ongoing efforts at the UN COPUOS.

As of June 2024, there are 43 parties to the Artemis Accords.[96]

The Moon Agreement

The 1979 Moon Agreement is a binding, multilateral agreement with 17 parties. The United States and other major space powers, such as Russia and the People's Republic of China (China), are not parties.[97] Saudi Arabia withdrew from the Moon Agreement in 2023, shortly after signing the Artemis Accords.[98]

Article 11 of the Moon Agreement is relevant to space mining. It states that the surface and subsurface of the Moon and its resources cannot become property of any country, intergovernmental organization, or nongovernmental entity.[99] The Moon Agreement directs countries to establish an international regime to govern the exploitation of space resources, in order to enable equitable sharing of space resources. The Moon Agreement also states, in Article 11, that the Moon is the common heritage of mankind, a principle that some observers have interpreted as "limit[ing] use and exploitation by mandating that any exploitation must be conducted according to rules established by the international community as a whole."[100]

In 2020, the Trump Administration issued Executive Order 13914, rejecting the position that the Moon Agreement "establishes the international legal framework concerning recovery and use of space resources," directing the Department of State to "object to any attempt … to treat the Moon Agreement as reflecting or otherwise expressing customary international law," and reaffirming that "Americans should have the right to engage in commercial exploration, recovery, and use of resources in outer space."[101]

"Artemis Accords: Principles for Cooperation in the Civil Exploration and Use of the Moon, Mars, Comets, and Asteroids for Peaceful Purposes," October 13, 2020, https://www.nasa.gov/wp-content/uploads/2022/11/Artemis-Accords-signed-13Oct2020.pdf.

95 NASA and the U.S. Department of State, "Artemis Accords: Principles for Cooperation in the Civil Exploration and Use of the Moon, Mars, Comets, and Asteroids for Peaceful Purposes," October 13, 2020, https://www.nasa.gov/wp-content/uploads/2022/11/Artemis-Accords-signed-13Oct2020.pdf.

96 U.S. Department of State, "Artemis Accords," June 2024, https://www.state.gov/artemis-accords/.

97 UN General Assembly, Resolution 34/68, "Agreement Governing the Activities of States on the Moon and Other Celestial Bodies," A/RES/34/68, December 14, 1979, https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXIV-2&chapter=24&clang=_en.

98 Stefan-Michael Wedenig and Jack Wright Nelson, "The Moon Agreement: Hanging By a Thread?" McGill Institute of Air and Space Law, January 2023, https://www.mcgill.ca/iasl/article/moon-agreement-hanging-thread.

99 UN General Assembly, "Agreement Governing the Activities of States on the Moon and Other Celestial Bodies," Resolution 34/68, A/RES/34/68, December 14, 1979, https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXIV-2&chapter=24&clang=_en.

100 Stefan-Michael Wedenig and Jack Wright Nelson, "The Moon Agreement: Hanging By a Thread?" McGill Institute of Air and Space Law, January 2023, https://www.mcgill.ca/iasl/article/moon-agreement-hanging-thread.

101 Executive Order 13914, "Encouraging International Support for the Recovery and Use of Space Resources," 85 *Federal Register* 20381, April 10, 2020, https://www.govinfo.gov/content/pkg/FR-2020-04-10/pdf/2020-07800.pdf.

Is Space Resource Extraction Viable?

Analyses on the economic viability of space resource extraction vary widely. This section provides a brief overview of such discussions.

The cost of launching extraction equipment into space and delivering it to its destination is a challenge for the viability of space resource extraction. Other challenges include the cost to develop the necessary technology and uncertainty about the amount and location of resources. For ISRU, these challenges may be offset by the avoided cost of launching and delivering fuel or oxygen or other needed resources to the in-space location where they are required.[102] In contrast, for space mining, there are additional costs associated with transporting extracted resources to Earth.

Because of these factors, analyses of the viability of space resource extraction, especially space mining, vary widely. Proponents note the prevalence of valuable resources in space, such as precious metals and other minerals. They argue that the high value of those resources, if transported to Earth, could make space mining profitable. Asterank—a database maintained by the company Planetary Resources—estimates the potential profit from mining some asteroids to be in the billions or even trillions of dollars.[103] Skeptics of this activity do not believe that extracting space resources for sale on Earth is economically viable. For instance, a 2020 study by the Science and Technology Policy Institute at the Institute for Defense Analyses found that, due to transportation and technology development costs, extracting precious metals or helium-3 from the Moon would not be economically viable before 2040.[104] Other observers believe that a viable market may form in the near term for ISRU but not for extraction for use on Earth.[105] A 2021 study by PricewaterhouseCoopers, for instance, projected that the market for fuel extracted from space resources would have an aggregate value of about $63 billion by 2040; the study anticipated that resource extraction for use on Earth would not be viable before 2040.[106]

Some entities, such as Asterank, project that celestial bodies may possess resources worth billions or even trillions of dollars. An article in Reuters, as another example, projected the collective hypothetical monetary value of the asteroid Psyche to be $10 quadrillion. Some researchers, however, have described the potential profits projected by Asterank and similar analyses as "highly tenuous," observing that their resource estimates would not pass the standard criteria for identifying proven reserves on Earth.[107] For example, USGS researchers noted that major commercial mining projects usually require a "quantitative resource assessment"; they judged that such an assessment for the Moon would likely require a "coordinated international resource

[102] Thomas J. Colvin, Keith Crane, and Bhavya Lal, "Assessing the Economics of Asteroid-Derived Water for Propellant," *Acta Astronautica*, vol. 176 (November 2020), pp. 298-305, https://doi.org/10.1016/j.actaastro.2020.05.029; Joe Reagan, "Mining Asteroids Will Benefit the Space Economy – but not on Earth," *Satnews*, November 2, 2023, https://news.satnews.com/2023/11/02/mining-asteroids-will-benefit-the-space-economy-but-not-on-earth-opinion/.

[103] Ian Webster, "Asterank," accessed April 2024, https://www.asterank.com/.

[104] Thomas J. Colvin et al., *Demand Drivers of the Lunar and Cislunar Economy*, Institute for Defense Analyses, Science and Technology Policy Institute, April 2020, pp. G-1–G-5, 83-87, https://www.ida.org/-/media/feature/publications/d/de/demand-drivers-of-the-lunar-and-cislunar-economy/d-13219.ashx.

[105] Joe Reagan, "Mining Asteroids Will Benefit the Space Economy – but not on Earth," *Satnews*, November 2, 2023, https://news.satnews.com/2023/11/02/mining-asteroids-will-benefit-the-space-economy-but-not-on-earth-opinion/.

[106] Luigi Scatteia and Yann Perrot, *Lunar Market Assessment: Market Trends and Challenges in the Development of a Lunar Economy*, PWC Research Paper, September 2021, p. 30, https://www.pwc.com.au/industry/space-industry/lunar-market-assessment-2021.pdf.

[107] Carol Dahl, Ben Gilbert, and Ian Lange, "Mineral Scarcity on Earth: Are Asteroids the Answer," *Mineral Economics*, vol. 33 (2020), pp. 29-41, https://doi.org/10.1007/s13563-020-00231-6.

evaluation campaign."[108] Some economic researchers have also suggested that, if space resources were extracted in sufficient quantities to achieve economies of scale, introducing those amounts into Earth's commodity markets "could substantially reduce their prices, changing expected profits into actual losses."[109]

Some proponents also note the potential strategic value of some space resources. Researchers from the Colorado School of Mines, for instance, noted that transitioning to clean energy could increase the demand for certain minerals. They asserted that the quality of certain mineral deposits available on Earth has decreased and that, driven by growing demand, extracting those resources from asteroids may be a worthwhile alternative to mining on Earth.[110] Along similar lines, in a 2023 hearing of the House Committee on Natural Resources, Subcommittee on Oversight and Investigations, two witnesses—Greg Autry and Lang Eric Sundby—pointed to China's "growing dominance" in terrestrial mineral supply chains as motivation for the United States to develop space resource extraction capabilities.[111]

Some proponents further suggest that extracting resources in space may be more ethical than terrestrial mining, which, they argue, can harm the environment and may involve the exploitation of workers. In the same 2023 hearing, the executive director of the University of Mississippi Center for Air and Space Law, Michelle Hanlon, stated that mining resources in space might "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."[112] On the other hand, another witness at that hearing, the founder and owner of Other Orb LLC, Moses Milazzo, raised concerns about the potential impact of space resource extraction on planetary defense, specifically, the protection of Earth from asteroid collisions. He noted that mining asteroids could create hazardous debris that might collide with Earth or could even "threaten the Earth by shifting the asteroid's orbit from a safe Earth flyby to a dangerous encounter."[113]

Considerations for Congress

Potential Gaps in Regulatory Oversight

Current law does not provide any U.S. federal agency with regulatory authority to oversee commercial space resource extraction. An issue for Congress may be whether regulatory

---

[108] Laszlo P. Keszthelyi et al., *Assessment of Lunar Resource Exploration in 2022*, Circular 1507, U.S. Geological Survey, 2023, p. 3, https://pubs.usgs.gov/circ/1507/cir1507.pdf.

[109] Carol Dahl, Ben Gilbert, and Ian Lange, "Mineral Scarcity on Earth: Are Asteroids the Answer," *Mineral Economics*, vol. 33 (2020), pp. 29-41, https://doi.org/10.1007/s13563-020-00231-6.

[110] Maxwell Fleming et al., "Mining in Space Could Spur Sustainable Growth," *Earth, Atmospheric, and Planetary Sciences*, vol. 120, no. 43 (October 16, 2023), https://doi.org/10.1073/pnas.2221345120.

[111] Testimony of Lang Eric Sundby, in U.S. Congress, House Committee on Natural Resources, Subcommittee on Oversight and Investigations, *The Mineral Supply Chain and the New Space Race*, hearings, 118th Cong., 1st sess., December 12, 2023, https://naturalresources.house.gov/uploadedfiles/testimony_sundby.pdf; Testimony of Greg Autry, PhD, in U.S. Congress, House Committee on Natural Resources, Subcommittee on Oversight and Investigations, *The Mineral Supply Chain and the New Space Race*, hearings, 118th Cong., 1st sess., December 12, 2023, https://naturalresources.house.gov/uploadedfiles/testimony_autry.pdf.

[112] Testimony of Michelle Hanlon, in U.S. Congress, House Committee on Natural Resources, Subcommittee on Oversight and Investigations, *The Mineral Supply Chain and the New Space Race*, hearings, 118th Cong., 1st sess., December 12, 2023, p. 6, https://naturalresources.house.gov/uploadedfiles/testimony_hanlon.pdf.

[113] Testimony of Moses Milazzo, PhD, in U.S. Congress, House Committee on Natural Resources, Subcommittee on Oversight and Investigations, *The Mineral Supply Chain and the New Space Race*, hearings, 118th Cong., 1st sess., December 12, 2023, p. 5, https://naturalresources.house.gov/uploadedfiles/testimony_milazzo.pdf.

authorities are needed to establish that the activity is conducted safely and with regard to U.S. international obligations.

Assigning regulatory authority to a federal agency might provide certainty for commercial space resource companies. Investors might be wary of uncertainty in the absence of a regulatory framework and may value federal oversight as an indicator of safety and viability. Companies might be able to point to federal oversight in fulfilling their fiduciary responsibilities to their investors and shareholders.[114]

On the other hand, to the extent that assigning regulatory authority results in new regulations, that might impose a burden on commercial space resource companies, particularly given the nascence of the industry and the technologies it might apply. Some in industry might perceive regulations as burdensome and hindering further development of these capabilities.

A related congressional concern may be whether additional regulatory oversight would help ensure that U.S. companies are behaving in accordance with international law. Organizations such as the Secure World Foundation argue that the United States "has a clear legal obligation under Article VI of the 1967 Outer Space Treaty, which requires that states authorize and continually supervise their non-governmental entities conducting space activities," including activities such as space resource extraction.[115]

Current legislative and executive branch proposals to assign regulatory authority for in-space commercial activities not currently regulated—referred to as "on-orbit authority" or "mission authorization"—may address space resource extraction if enacted. As ordered to be reported out of committee, H.R. 6131 (Commercial Space Act of 2023) would assign mission authorization for all "space objects" to the Department of Commerce.[116] In contrast, the National Space Council released a proposal for authorization and supervision of "commercial novel space activities" on December 20, 2023,[117] assigning licensing authority for human activities in space and the transportation of goods between destinations in space to the Department of Transportation, and licensing authority for other space activities not currently regulated to the Department of Commerce. Under the National Space Council proposal, some aspects of resource extraction might fall under each department's auspices.

Research and Development

Congress may consider whether to support additional R&D for space resource extraction. One option would be to establish new R&D initiatives. For instance, in a 2023 hearing of the House Committee on Natural Resources, a witness recommended that Congress provide funding for R&D into "dual use mining technologies," or technologies that support both space resource

---

[114] Dan Dumbacher et al., *The U.S. Imperative for Mission Authorization and Supervision of Commercial Space Activities*, American Institute of Aeronautics and Astronautics, Washington, DC, December 2021, https://www.aiaa.org/docs/default-source/uploadedfiles/issues-and-advocacy/policy-papers/the-u-s-imperative-for-mission-authorization-and-supervision-of-commercial-space-activities.pdf.

[115] Secure World Foundation, "Approaches for Authorization and Supervision," written submission to the National Space Council In-Space Authorization and Supervision Policy Listening Sessions, December 2022, p. 1.

[116] H.R. 6131 was ordered to be reported but has not been. While the official reported text of H.R. 6131 is not yet available, the amendments adopted during the markup did not appear to change the provisions of the introduced bill related to the proposed authorities for the Department of Commerce. (House Committee on Science, Space, and Technology, "Full Committee Markup of H.R. 6213 & H.R. 6131," November 29, 2023, https://science.house.gov/2023/11/markup-h-r-6213-h-r-6131.)

[117] The White House, "FACT SHEET: U.S. Novel Space Activities Authorization and Supervision Framework," December 20, 2023, https://www.whitehouse.gov/briefing-room/statements-releases/2023/12/20/fact-sheet-u-s-novel-space-activities-authorization-and-supervision-framework/.

extraction and advanced terrestrial mining.[118] Similarly, a collaborative study led by the United Launch Alliance recommended that the U.S. government develop precursor prospecting missions to quantify resources on the Moon, which would in turn inform the design of extraction and transportation systems.[119]

To that end, Congress may direct a federal agency or an independent technical organization to conduct a study on potential research needs. For instance, a relevant bill of the 118th Congress—H.R. 4152—would direct NASA and the Department of Commerce to submit a report to Congress assessing the merits of and options for establishing an institute relating to space resources.

Another option would be to provide additional funding to existing programs or to direct agencies to continue existing or recently cancelled efforts. For instance, the collaborative study led by the United Launch Alliance also recommended that the U.S. government increase its support of key technologies for ISRU and facilitate further technology development by increasing R&D partnerships across the U.S. government and developing a prototype pilot facility for ISRU. As another example, a witness at the aforementioned 2023 hearing suggested that Congress allocate additional funding to NASA's Science Mission Directorate for "the continued exploration of lunar and asteroid missions." Some of the existing and recently cancelled programs at NASA and other agencies are discussed above in the section "What Are the Existing U.S. Efforts in Space Resource Extraction?"

Alternatively, Congress may determine that existing R&D programs are sufficient or that any additional R&D efforts should be funded and developed by industry.

International Engagement

Various countries and their respective space agencies continue to discuss whether public or private space resource extraction is permissible under existing treaties and what an international governance framework might look like. An issue for Congress may be whether the executive branch should continue to engage directly with U.S. partners and allies and in international fora—such as the UN COPUOS—in order to address space resource extraction. A key consideration in such engagements may be whether the U.S. government should continue to affirm that its citizens have the right to obtain, use, and sell space resources, provided they do so in compliance with applicable law, including the international obligations of the United States.

Options for Congress could include recommendations that the executive branch pursue an international treaty that addresses space resource extraction[120] or consider legislation authorizing the President to conclude a binding executive agreement that addresses the topic.[121] Should a new treaty or other international agreement be proposed and adopted by enough countries, it may explicitly allow and provide a framework for public and private space resource extraction. Some scholars advocate for such an approach, noting that if the United States encourages the

---

[118] Testimony of Greg Autry, PhD, in U.S. Congress, House Committee on Natural Resources, Subcommittee on Oversight and Investigations, *The Mineral Supply Chain and the New Space Race*, hearings, 118th Cong., 1st sess., December 12, 2023, p. 6, https://naturalresources.house.gov/uploadedfiles/testimony_autry.pdf.

[119] David Kornuta et al., Commercial Lunar Propellant Architecture: A Collaborative Study of Lunar Propellant Production, March 2019, https://www.osti.gov/pages/servlets/purl/1503160.

[120] For information on potential congressional mechanisms relating to international instruments, see CRS Legal Sidebar LSB11048, *International Agreements (Part I): Overview and Agreement-Making Process*, by Steve P. Mulligan, and CRS Legal Sidebar LSB11049, *International Agreements (Part II): Examining Tools for Congressional Influence Over International Instruments*, by Steve P. Mulligan.

[121] For background on the distinction between treaties and executive agreements, see CRS Report RL32528, *International Law and Agreements: Their Effect upon U.S. Law*, by Steve P. Mulligan, pp. 3-11.

development of a new international agreement, it may "allow for a more stable environment in space" and "reaffirm the demilitarization of space," which "will help ensure conflicts involving space mining do not arise in the near future."[122] Others say that it is unlikely that a new agreement on outer space activities would be adopted, due to continued disagreements among major space powers.[123]

Another congressional option could be to urge that the executive branch consider amending the Outer Space Treaty or other existing treaties or agreements to address space resource extraction. A researcher at the RAND Corporation notes that amending and updating the Outer Space Treaty "to establish more detailed binding rules could be a crucial and productive first step" to addressing a variety of space issues, although "significant political and diplomatic challenges" exist.[124] A professor emerita at the University of Mississippi School of Law argues that "it would be impossible to get a new treaty or amend the existing treaty," due to ongoing disagreements among major space powers.[125]

In addition to those options, Congress may continue its oversight of the executive branch's international engagements on public and private space mining. These engagements may include efforts to establish norms of behavior and standard practices and to encourage other countries to adopt them. Doing so may form the basis for international customary law if enough countries decide to adhere to a particular framework out of a sense of legal obligation.[126] Some stakeholders believe that such engagement may have the practical effect of preempting other countries from establishing a different framework that may be less favorable to public and private U.S. interests. For instance, researchers at the RAND Corporation in a discussion of space resource extraction recommended that the U.S. government cooperate with other space powers to define a governance framework, rather than allow the establishment of "competing governance systems … further increasing the potential for conflict."[127]

Author Information

Rachel Lindbergh
Analyst in Science and Technology Policy

[122] Todd Skauge, "Space Mining & Exploration: Facing a Pivotal Moment," *The Journal of Corporation Law*, vol. 45, no. 3 (August 2021), https://jcl.law.uiowa.edu/sites/jcl.law.uiowa.edu/files/2021-08/Skauge_Final_Web.pdf.

[123] Rachel Lindbergh et al., *Assessment of Global Norms of Behavior and Legal Regimes Related to On-Orbit Activities*, Institute for Defense Analyses STPI, April 2022, p. vi, https://www.ida.org/-/media/feature/publications/a/as/assessment-of-global-norms-of-behavior-and-legal-regimes-related-to-on-orbit-activities/d-28849.ashx; Jason Krause, "The Outer Space Treaty Turns 50. Can It Survive a New Space Race?" *American Bar Association Journal*, April 1, 2017, https://www.abajournal.com/magazine/article/outer_space_treaty.

[124] Douglas Ligor, "Reduce Friction in Space by Amending the 1967 Outer Space Treaty," *War on the Rocks*, August 26, 2022, https://warontherocks.com/2022/08/stabilize-friction-points-in-space-by-amending-the-1967-outer-space-treaty/.

[125] Jason Krause, "The Outer Space Treaty Turns 50. Can It Survive a New Space Race?" *American Bar Association Journal*, April 1, 2017, https://www.abajournal.com/magazine/article/outer_space_treaty.

[126] For more information, see CRS Report RL32528, *International Law and Agreements: Their Effect upon U.S. Law*, by Steve P. Mulligan.

[127] Jan Osburg and Mary Lee, "Governance in Space: Mining the Moon and Beyond," RAND, November 18, 2022, https://www.rand.org/pubs/commentary/2022/11/governance-in-space-mining-the-moon-and-beyond.html.

Disclaimer