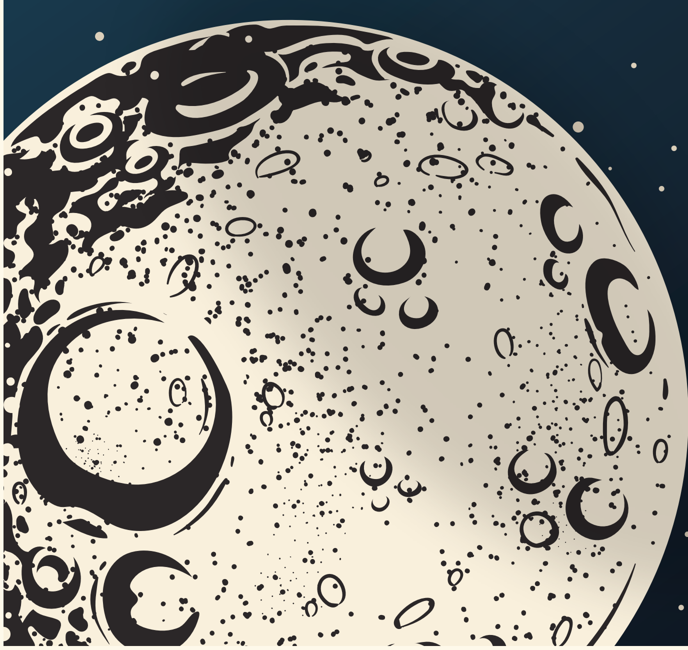
OCTOBER 2024

Salmon Swimming Upstream

CHARTING A COURSE IN CISLUNAR SPACE



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A REPORT OF THE CSIS AEROSPACE SECURITY PROJECT

CSIS | CENTER FOR STRATEGIC & INTERNATIONAL STUDIES

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EXECUTIVE SUMMARY

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"I think we're going to the moon because it's in the nature of the human being to face challenges. It's by the nature of his deep inner soul . . . we're required to do these things just as salmon swim upstream."

— Neil Armstrong, 1969[1]

Humankind has had an on-again, off-again relationship with the Moon. During the 1960s, over 63 spacecraft, including several crewed Apollo missions, launched to the Moon.[2] In contrast, during the 1980s, no nation launched a lunar mission. Over the course of the following decades, however, the world gradually fell back in love with our closest celestial neighbor. During the last four years alone, 11 nations and the European Space Agency have all sent payloads and spacecraft to the Moon.

Most of these missions were operated by government agencies and focused on scientific research and exploration.[3] However, a few were carried out by companies such as Intuitive Machines and Astrobotic.[4] A number of countries plan to send humans to the lunar surface within the next 10 years, and some have plans to establish a long-term human presence either in lunar orbit or on the Moon's surface.[5] At the time of writing, there was probably just one active mission on the lunar surface, a Chinese lander and associated rover, and several active spacecraft in lunar orbits.[6]

While the majority of future space endeavors will undoubtedly take place near Earth, more and more activities will likely happen in cislunar space, or the area between geosynchronous Earth orbit and the Moon. From the perspective of the United States, reasons to focus attention on cislunar space include lunar science and exploration, future crewed missions, and concerns about China's space ambitions.[7]

CISLUNAR CHALLENGES

Operating in cislunar space presents new technical and policy challenges that the United States will want to consider. While exponential growth in cislunar activities is unlikely over the next 10 years, there will be modest expansion. To maximize the chances of success for U.S. cislunar missions and ensure the long-term sustainability and safety of cislunar space, the United States should assume a global leadership role and take actions, sooner rather than later, to address the anticipated cislunar challenges discussed in this report.

The list of related operational challenges is long. There is little space situational awareness (SSA) in cislunar space. The Global Positioning System (GPS) was not designed for this region, so without enhancements it cannot reliably provide cislunar navigation and timing services.[8] In classical orbital mechanics, the motion of a near-Earth satellite can be predicted as part of a two-body problem (i.e., Earth and the spacecraft). In cislunar space, this two-body problem poorly predicts motion. Other issues, such as the impacts of cosmic radiation and lunar dust on equipment and humans, also pose hazards to cislunar missions.

The space governance and operator coordination issues concerning cislunar activities are equally complex. Internationally, there are no agreed-upon rules of the road for operating in cislunar space or best practices for cislunar debris mitigation. Though cislunar space is covered by the treaties that underpin international space law, these treaties have sizable gaps and are subject to conflicting interpretations. Fortunately, while not focused on space, there are other non-space international treaties and frameworks that could offer lessons for space governance.

REPORT OBJECTIVES AND APPROACH

The goal of this report is to examine and assess oft-heard claims of a new Moon race, growing lunar economy, and need to extend military power into cislunar space.[9] To write this report, the authors researched government and private sector activities planned for cislunar space by over 10 nations, covering the next decade. They interviewed cislunar stakeholders from government agencies, private companies, and academia. Additionally, the authors assessed cislunar reports prepared by other researchers.

Though there is certainly a lot of buzz about cislunar growth, the authors of this report found evidence of only a modest increase in cislunar activities over the next decade compared to the past 10 years. Additionally, the authors found little sign of a business case for cislunar activities that is not closely tied to government funding and support. Almost all cislunar activities, no matter the mission's nation of origin, have a civilian focus. The authors also could not identify any compelling strategic military value from cislunar space and did not foresee one developing in the next decade that could make a decisive difference in any conflict between the United States and China, Russia, or another nation-state. However, national security organizations may want access to cislunar SSA data for surveillance purposes.

But even under these conditions—modest growth in overall cislunar activities, no clear cislunar use cases without governments as a customer, and no clear strategic military value of cislunar space—there are reasons to focus on cislunar space and identify and address challenges facing cislunar operators. Through the Artemis program, the United States is establishing significant cislunar equities, building the foundation for sustainable human activity in cislunar space, investing in lunar infrastructure, and creating an ecosystem of commercial cislunar services. Addressing cislunar challenges discussed in this report is critical to the success of these endeavors. This report specifically seeks to analyze and recommend ways U.S. decisionmakers can address cislunar governance, coordination, and infrastructure challenges.

In conclusion, this report's authors could find no evidence of a lunar gold rush and no indication of a real commercial lunar economy. Cislunar activity is supported almost exclusively by government spending.

On governance challenges, the report first provides background on international treaties and national U.S. space policies, laws, and regulations. Later, the report discusses specific policy and governance gaps that should be addressed to promote a safe and sustainable cislunar environment. The report also introduces and provides background on several non-space international frameworks that govern other areas with similar characteristics as cislunar space, such as Antarctica, the Arctic, and international air and maritime domains. The authors frequently cite these existing frameworks when describing models and approaches that could apply to cislunar space.

The report also outlines operational and infrastructure challenges confronting operators of cislunar missions, explaining why these cislunar challenges are both different and similar to those confronting operators with missions in orbits closer to Earth. The authors note that infrastructure challenges, such as generating power and ensuring communications, are primarily solved by hardware and equipment—whereas operational challenges, such as traffic coordination and collision avoidance, require both technical solutions and operator-to-operator coordination.

REPORT RECOMMENDATIONS

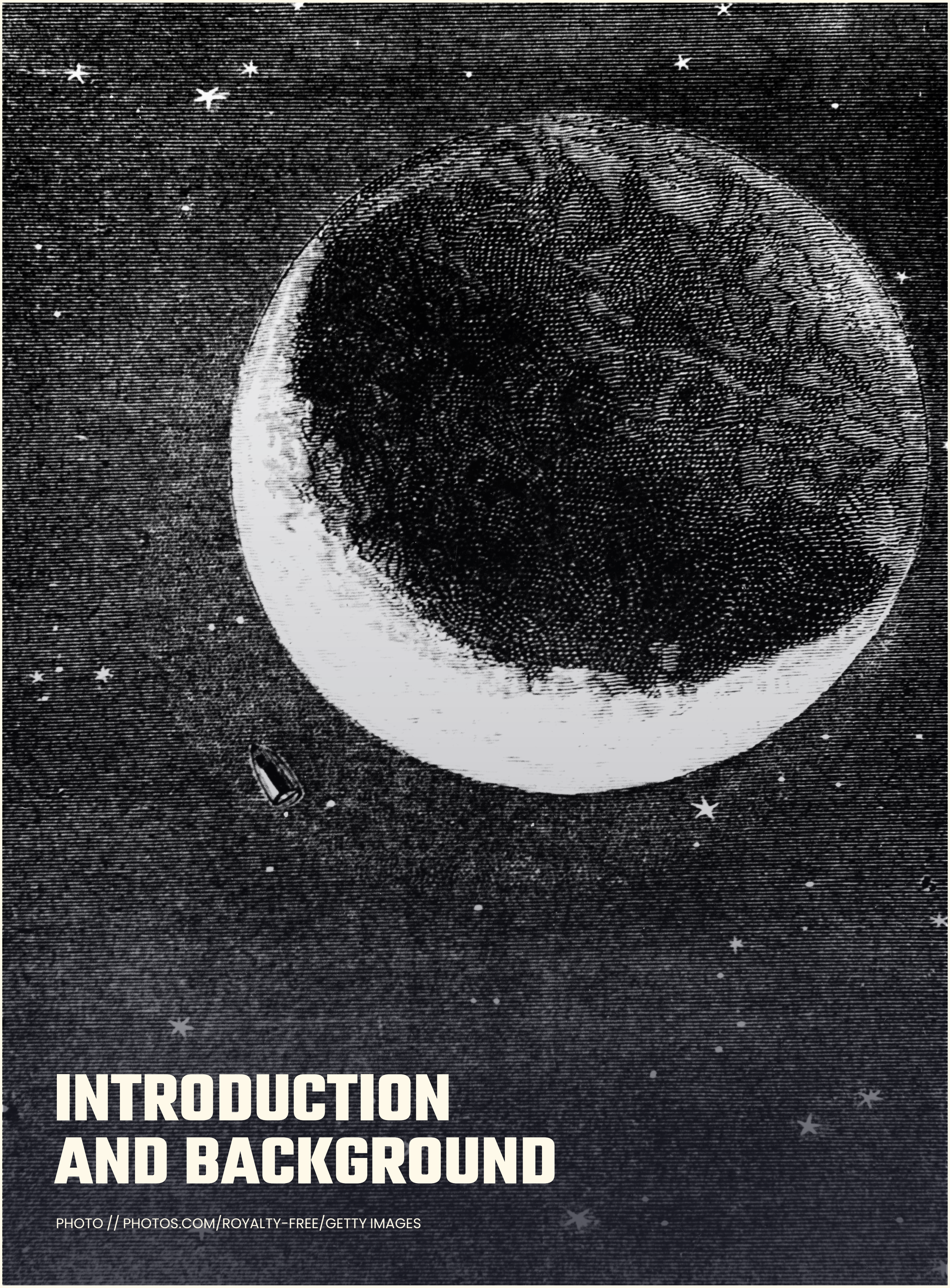
Finally, the report offers several key recommendations for consideration by U.S. policymakers. First, the United States should work to find an understanding with China on addressing international space governance and operational coordination challenges related to cislunar space, because the vast majority of cislunar activity over the next decade will be tied to these two nations. Second, the United States should consider whether it furthers U.S. interests to keep cislunar space nonmilitarized, taking an approach from the U.S. playbook toward Antarctica in the 1950s. Third, the United States should consider international approaches to building and operating cislunar infrastructure, combining resources, preventing duplication, and maximizing the gain for the cost to U.S. taxpayers.

In conclusion, this report's authors could find no evidence of a lunar gold rush and no indication of a real commercial lunar economy. Cislunar activity is supported almost exclusively by government spending. Certainly, Britain's famed eighteenth-century economist Adam Smith would not characterize the cislunar environment as a market-based economy. There are currently no clear strategic military benefits derived from cislunar space derived from cislunar space, with little chance a cislunar space system could influence the outcome of a conflict on Earth.

EVOLVING FUTURE CONSIDERATIONS

Maybe someday, in the distant future, there will be a market-based lunar economy and a reason to have a military presence in cislunar space. This may happen if a cislunar activity could unexpectedly produce significant commercial value, such as mining of rare earth elements that could cost-effectively be returned and sold on Earth. This may also happen if the United States and China, ignoring the precedent of Antarctica, cannot agree to forestall the equivalent of a cislunar colonial land grab and resulting rush of military assets to the cislunar region. Additionally, dramatically lowering transportation costs to the Moon may also generate new lunar business cases.

Ultimately, the calculus fundamentally changes if—probably when—large numbers of humans start living on the Moon and in other parts of the solar system. Many of us, these authors included, foresee that future. But that is not on the 10-year plan, probably not even on the 25-year one. There are, however, strong reasons to go to the Moon today and in the foreseeable future: to explore the unknown, learn, and advance science for the sake of all humankind. That is reason enough to address the challenges described in this report.



INTRODUCTION AND BACKGROUND

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DEFINING "CISLUNAR SPACE"

In this report, "cislunar space" refers to the area between geosynchronous orbit around Earth (about 36,000 kilometers from Earth's surface) and the Moon (approximately 384,000 kilometers from Earth's surface, on average).[10] Orbits around the Moon, trajectories to and from the Moon, the five Earth–Moon Lagrange points (L_1, L_2, L_3, L_4, and L_5), and the Moon itself are also included in this report's definition. Effectively, three different environments in which space operations can occur are included in this definition: the Moon's surface, lunar orbits, and Earth orbits and trajectories to and from the Moon.

Like the Moon itself, most objects in cislunar space are orbiting Earth, though some objects are also orbiting the Moon. However, due to Earth's gravitational pull, orbits higher than 700 kilometers above the lunar surface are not stable.[11] To further complicate matters, the mass of the Moon is irregularly distributed, which renders its gravitational field uneven. This means that at altitudes lower than 100 kilometers from the Moon's surface, only four lunar orbital inclinations support stable orbits.[12] Objects attempting to orbit the Moon below 100 kilometers at other inclinations must perform frequent station-keeping maneuvers and expend fuel to remain in orbit.

Objects in cislunar space are affected not only by Earth's gravitational effects but also by the Moon's gravity. As with any two large celestial bodies, there are five Lagrange points around the Earth and Moon at which the gravitational pull of the Earth and Moon is exactly equal to the amount of centripetal force needed for a small object, such as a satellite or spacecraft, to move with them.[13] Due to these gravitational dynamics, the Lagrange points are nearly stationary relative to the Earth-Moon rotating frame.[14]

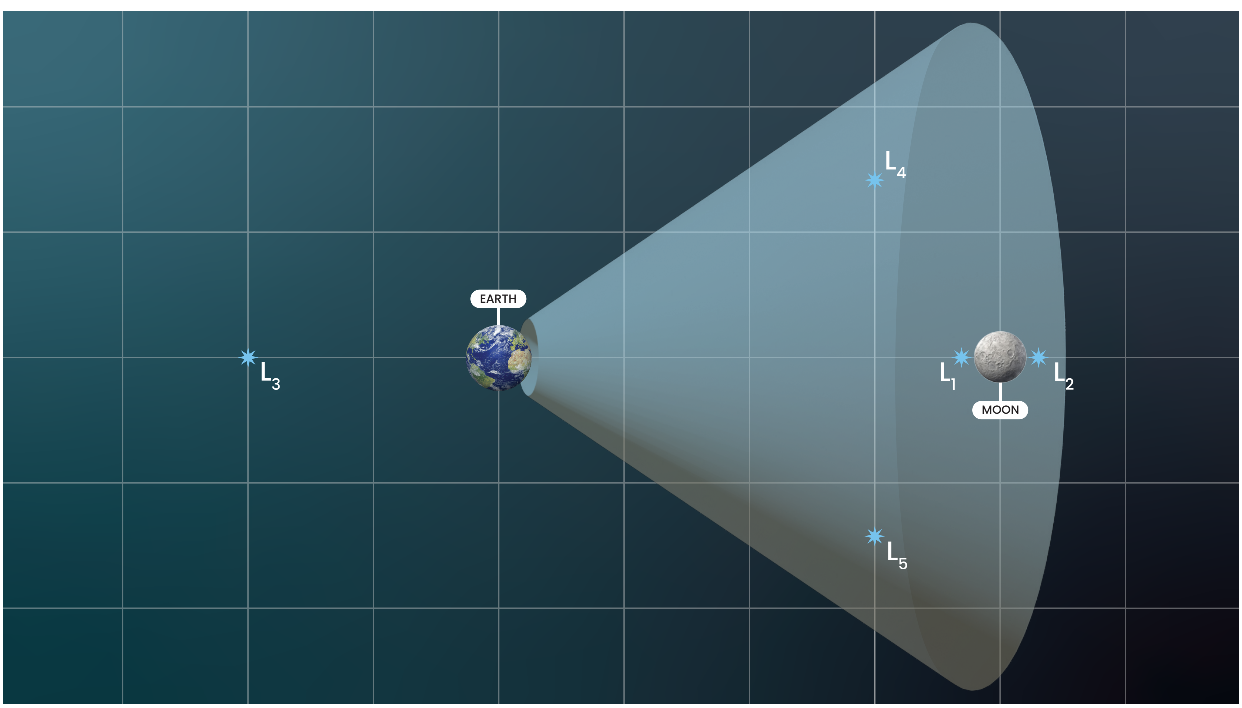
HISTORY OF CISLUNAR SPACE

Since Russia's Luna 1 became the first spacecraft to reach the vicinity of the Moon in January 1959, approximately 140 missions have been launched to the Moon, either landing on the lunar surface, entering lunar orbit, or conducting a lunar flyby.[15] Thirteen countries and the the European Space Agency (ESA) have launched spacecraft toward the Moon. The first U.S. spacecraft to reach the vicinity of the Moon was Pioneer 4, which conducted a lunar flyby in March 1959.[16] In 1990, Japan became the third nation to launch a lunar probe, called Hiten, and the third nation to reach the lunar surface when Hiten's small orbiter, Hagoromo, was intentionally crashed into the Moon in 1993 after completing several lunar orbits.[17]

The majority of lunar missions have been launched and managed by government entities, with only four spacecraft ever sent to the Moon operated by private sector organizations. Cislunar space saw the most activity at the height of the space race between the 1950s and 1970s. Interest in the Moon quickly declined by the 1980s; as

Figure 1: Cislunar Region with Cone Denoting the Area of Greatest Cislunar Activity

Source: CSIS Aerospace Security Project.



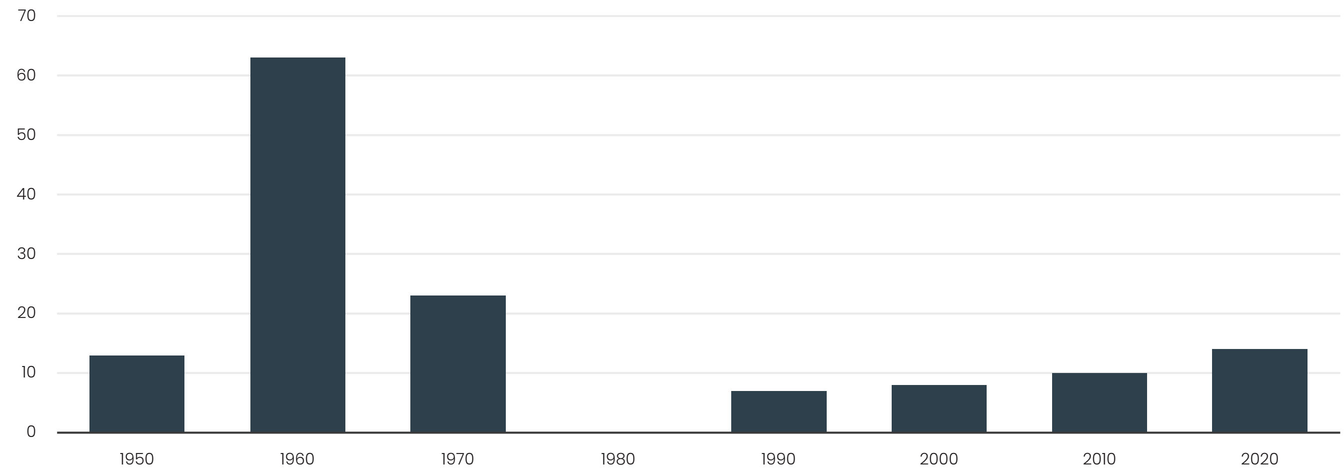


Figure 2: Launches to the Moon by Decade

Source: "Moon Missions," NASA, accessed August 17, 2024, https://science.nasa.gov/moon/missions/.

already noted, there were zero missions to the Moon from 1980 to 1989. Although there has been a steady increase in cislunar activity since 1990, the total number of lunar missions since then is only about two-thirds that of missions in just the 1960s. Almost all cislunar traffic to date has resulted from spacecraft traveling to the Moon, though spacecraft bound for other locations in the solar system have passed through cislunar space.[18]

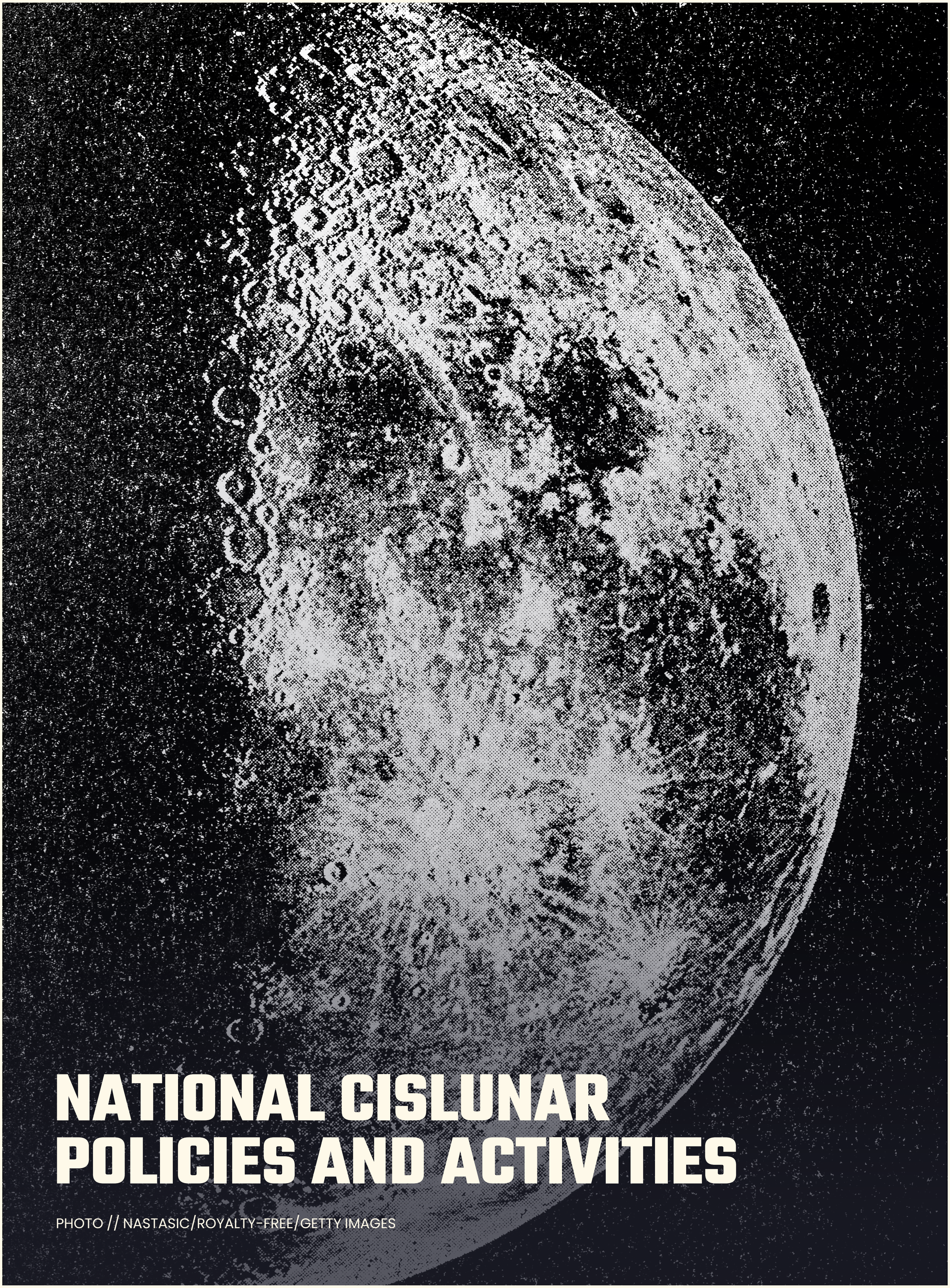
Over the past decade, between 2014 and 2024, about 20 missions sent from Earth have transited cislunar space on their way to the Moon.[19] To place this number into context, over 12,000 objects—including satellites, scientific probes, landers, crewed spacecraft, and components of space stations—have been launched into space during this same period.[20] While the number of missions through cislunar space has increased over the past four decades, the increase is small compared to the exponential growth in the number of satellites launched into orbits closer to Earth. Overall, missions through cislunar space are just a small fraction of the total number of spacecraft launched from Earth.

	TOTAL	LUNAR ORBIT	LUNAR LAGRANGE ORBIT	LUNAR SURFACE
2014	241	1	0	0
2015	222	0	0	0
2016	221	0	0	0
2017	456	0	0	0
2018	452	1	1	2
2019	586	1	0	2
2020	1,274	0	0	1
2021	1,813	0	0	0
2022	2,477	5	0	2
2023	2,890	0	0	3
2024	1,634	2	0	1

Table 1: New Space Objects by Year

Note: Data is current as of September 26, 2024.

Source: "Outer Space Objects Index," UN Office for Outer Space Affairs, https://www.unoosa.org/oosa/osoindex/index.jspx?lf_id=..



NATIONAL CISLUNAR POLICIES AND ACTIVITIES

PHOTO // NASTASIC/ROYALTY-FREE/GETTY IMAGES

Today, cislunar activity remains limited because there are few commercial cislunar use cases and requirements that are independent of a government operator or customer. Most lunar activities are funded and operated by governments, primarily for scientific research and exploration to better understand the Moon and its environs. Most commercial lunar missions are also closely tied to government science and research requirements and funding. For example, Japanese company ispace and U.S. companies Astrobotic and Intuitive Machines have already launched and are planning more commercial missions to carry government-sponsored scientific payloads to the Moon, as well as nongovernment payloads.[21]

In addition to conducting scientific research, many Moon missions aim to demonstrate technologies such as lunar rovers that could be used on future missions. Two upcoming lunar missions, part of the Chang'e program operated by China's national space agency, will test technologies intended to support a future long-term uncrewed lunar base.[22] In addition to supporting NASA's Commercial Lunar Payload Services (CLPS) program, future missions from Astrobotic, Firefly Aerospace, and Intuitive Machines, among others, will carry a variety of payloads, including rovers, hoppers, sensors, scientific experiments, and small satellites for private sector organizations and space agencies from around the world looking to test their technologies on and in orbit around the Moon.

Other organizations are looking at using the Moon to preserve Earth's cultural heritage and biodiversity. For example, the UN Educational, Scientific and Cultural Organization (UNESCO) intends to send a memory disk containing the UNESCO preamble in 275 human languages to the lunar surface on ispace's upcoming Hakuto-R 2.[23] Additionally, a group of scientists wants to use the Moon to create a biorepository of cryopreserved seeds and living cells as a safeguard against possible threats to life on Earth.[24] In a similar vein, Interstellar Lab's Mission Little Prince aims to grow flowers on the Moon in an environment-controlled plant pod.[25]

For the near future, use cases such as scientific research, technology demonstrations, and, on a smaller scale, disaster planning are the drivers for cislunar traffic. Notably, the United States and China are pursuing ambitious agendas to create human habitats in lunar orbit and land people on the Moon. Over the next several years, the authors of this report anticipate around 40 significant missions launching toward cislunar space, not including missions that merely transit cislunar space bound for deep space destinations.

Table 2: Significant Future Cislunar Missions

Source: Authors' research and analysis.

EXPECTED LAUNCH YEAR	MISSION NAME	COUNTRY OF ORIGIN
2024	Blue Ghost M1 (Firefly Aerospace), CLPS Mission	United States
2024	Hakuto-R 2	Japan
2024	Intuitive Machines 2 - Athena, CLPS Mission	United States
2024	Lunar Trailblazer, SIMPLEx Mission	United States
2025	Artemis II	United States
2025	Griffin Mission 1 (Astrobotic), CLPS Mission	United States
2025	Beresheet 2	Israel
2025	Blue Moon Mark 1 (Blue Origin), Mission 1	United States
2025	DESTINY+	Japan
2025	Intuitive Machines 3, CLPS Mission	United States
2025	Lunar Polar Exploration Mission (LUPEX)	Japan and India
2025	Lunar Surface Access Service 1 (LSAS-1)	Germany and Israel
2025	Oracle-Mobility	United States
2026	Artemis III	United States
2026	AYAP 1	Turkey
2026	Flexible Logistics and Exploration (FLEX) Mission 1 (Astrolab)	United States

2026	Chang'e 7	China
2026	Blue Ghost M2 (Firefly Aerospace), CLPS Mission	United States
2026	APEX 1.0 (Team Draper), CLPS Mission	United States
2026	Starship Human Landing System (HLS) Uncrewed Demonstration	United States
2027	Luna 26	Russia
2027	Lunar Gateway: Power and Propulsion Element (PPE) and Habitation and Logistics Outpost (HALO)	United States
2027	Oracle-Prime	United States
2027	ZeusX	Singapore
2028	Artemis IV and Lunar Gateway: I-Hab	United States
2028	Chandrayaan-4	India
2028	Chang'e 8	China
2028	Gateway Logistics Services, Mission 1	United States
2028	Luna 27a	Russia
2028	Luna 27b	Russia
2030	Luna 28	Russia
2030	Artemis V and Lunar Gateway: European System Providing Refueling, Infrastructure and Telecommunications (ESPRIT)	United States
2030	Blue Moon Mark 1 (Blue Origin), Uncrewed Demonstration	United States
2030	Unnamed Chinese crewed mission	China
2031	Argonaut, European Large Logistics Lander (EL3) Mission 1	European Space Agency
2031	Artemis VI and Lunar Gateway: Airlock and External Robotics	United States
2032	Artemis VII	United States

At this point, the report authors should acknowledge the challenges in counting cislunar missions. Rather than attempting to count all missions, the authors identified significant future missions that represented the most considerable and impactful cislunar undertakings.

Many future cislunar missions look like matryoshka, or Russian nesting, dolls; they are complex systems of systems, with some providing lunar ridesharing. Most Artemis missions have many moving parts, including the Orion spacecraft, modules of the Lunar Gateway, and space vehicles associated with the Starship Human Landing System (HLS). Additionally, China's Chang'e 6 mission included a lander, ascender, return vehicle, mini rover, and an orbiter built by Pakistan. The future Chang'e 8 mission is also expected to include international payloads. Each Chang'e and Artemis mission is included in the significant mission list.

The CLPS program epitomizes the concept of lunar ridesharing, transporting NASA payloads and creating opportunities for smaller companies, international partners, and other organizations to send missions, including scientific instruments, rovers, and orbiters, to the Moon. This approach is

Many future cislunar missions look like matryoshka, or Russian nesting, dolls; they are complex systems of systems, with some providing lunar ridesharing.

diversifying the types of entities launching to cislunar space and increasing the number of individual organizations with payloads in lunar orbit and on the Moon's surface.

This report considers each CLPS mission a significant mission but not individual payloads, though many of these payloads are described in the report. In general, this report does not count instruments or experiments that remain associated with or near another spacecraft, lander, or rover as a significant mission. For example, a memory disk sponsored by UNESCO that will be carried on Hakuto-R 2 is not included in the significant mission tally.

If the report authors could not find clear indications of funding or recent progress for a future concept or mission—meaning the mission's existence is based only on a press release—the authors did not include the mission in Figure 1. For missions beyond 2030, it was often difficult to differentiate real plans from aspirations, as many decisions on government funding for activities so far into the future have yet to be made. The authors also questioned whether Russia has the financial resources to execute its upcoming cislunar plans, which include at least three lunar missions, but still includes those on the significant mission list.

Additionally, the fully assembled Lunar Gateway is not specifically listed in the table, though completion of the station will be a significant achievement. Finally, one mission in the table—DESTINY+—has a lengthly transit time through cislunar space on its way to the parent body of the Geminids meteor shower.[26]

United States

Policies

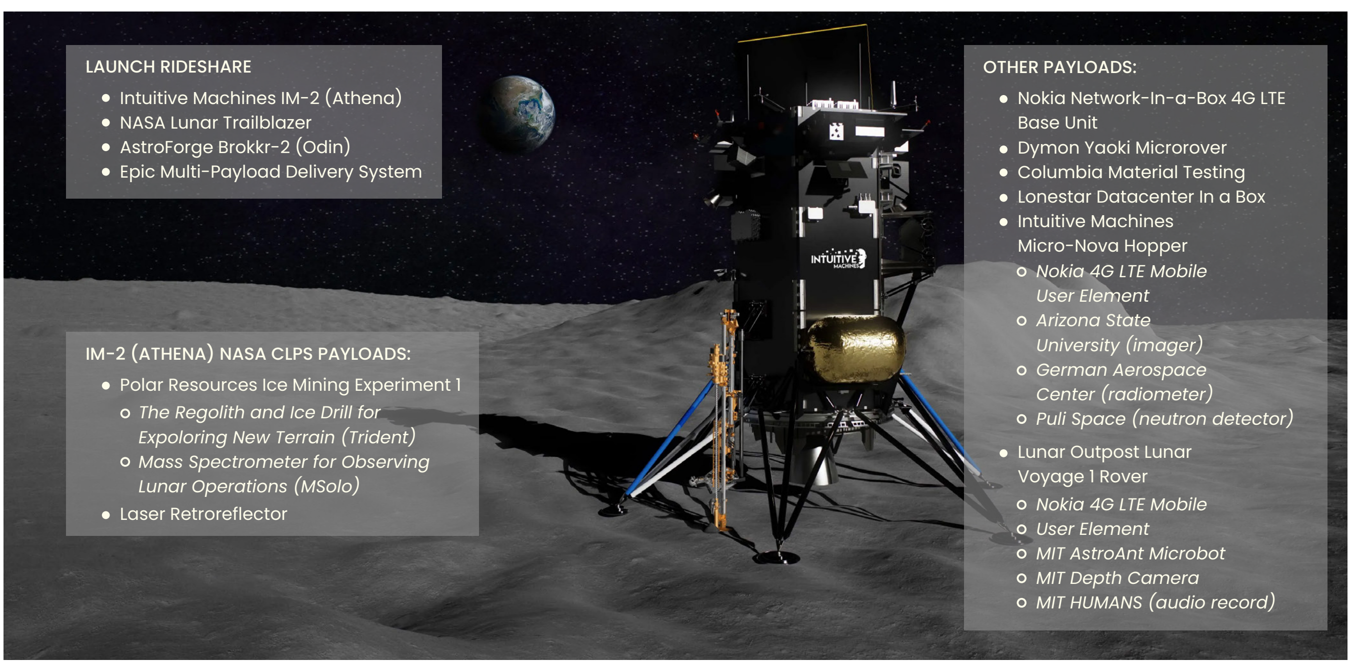
In December 2021, the White House released the United States Space Priorities Framework, which outlined various goals related to national and economic security and scientific advancement for U.S. activities in space.[27] Those goals include

- maintaining "leadership in space exploration and space science";
- advancing "the development and use of space-based Earth observation capabilities that support action on climate change";
- fostering "a policy and regulatory environment that enables a competitive and burgeoning U.S. commercial space sector";
- protecting "space-related critical infrastructure" and strengthening "the security of the U.S. space industrial base";
- defending "national security interests from the growing scope and scale of space and counterspace threats";
- investing in science, technology, engineering, and mathematics education;
- playing a lead role in "strengthening global governance of space activities";
- bolstering "space situational awareness sharing and space traffic coordination"; and
- prioritizing "space sustainability and planetary protection."

The framework emphasizes retaining U.S. leadership in space and broadening and deepening international space collaboration. Though this document does not focus on cislunar space specifically, its priorities apply to all U.S. activities and initiatives in space.

Figure 3: Example Commercial Lunar Mission Supporting CLPS - Intuitive Machines IM-2

Source: Intuitive Machines (reprinted with permission).



In addition to these national space priorities, the White House Office of Science and Technology Policy (OSTP), together with the National Science and Technology Council, developed and published the National Cislunar Science and Technology Strategy in 2022. The strategy seeks to foster interagency cooperation and advance U.S. cislunar science and technology leadership. It defines four objectives: "support research and development to enable long-term growth in Cislunar space"; "expand international S&T [science and technology] cooperation in Cislunar space"; "extend U.S. space situational awareness capabilities into Cislunar space"; and "implement Cislunar communications and PNT [positioning, navigation, and timing] capabilities."[28] Though OSTP does not itself direct funding or administer space programs, its cislunar strategy will likely influence spending and priorities across the U.S. federal government.

Although China is not specifically mentioned in the United States Space Policy Framework or National Cislunar Science and Technology Strategy, Beijing's central role as a motivator for U.S. cislunar activities is undeniable. Some U.S. experts have argued that China could obtain a first-mover advantage and become the dominant power in cislunar space, to the detriment of U.S. interests.[29] Additionally, the current NASA administrator, Bill Nelson, has expressed concern that China could try to restrict U.S. access to lunar resources if it establishes a long-term presence on the Moon before the United States does.[30] Other U.S. experts worry about the impacts of China's cislunar activities on U.S. prestige and influence, framing cislunar plans within the context of broader geopolitical competition between the two powers.[31]

Finally, many government actors—including the United States, China, Russia, and the North Atlantic Treaty Organization (NATO)—have stated that space could be used for warfighting. Though cislunar space is not the primary focus of U.S. military attention on the space domain, the Department of Defense (DoD) is leading several initiatives, described later in this report, focused on cislunar space. However, it is not clear how cislunar space fits into the overall national security strategy, because the DoD has neither articulated broad cislunar goals nor put forward a cislunar strategy.

Enacted Law

Over the past 90 years, the United States has enacted numerous laws related to military, civilian, and commercial space activities, which would apply not only to near-Earth orbits but also to cislunar space. Title 51 of U.S. Code contains laws related to national and commercial space programs. Applicable laws related to defense and military space programs are mostly found in Title 10.

The **Communications Act** of 1934 provided the basis for federal regulation of telephone, telegraph, and radio communications and was later amended to include requirements for commercial satellite licensing and use of radio spectrum. The act established the Federal Communications Commission (FCC) to regulate use of these technologies in the United States. This law also applies to U.S. entities wanting to use spectrum to communicate from, to, and in cislunar space.[32]

The **National Aeronautics and Space Act** of 1958 separated military and civilian space government functions and emphasized the peaceful character of U.S. pursuits in space. The act also established NASA, the first U.S. government organization dedicated to the civilian use of space.[33]

The **Commercial Space Launch Act** of 1984 provided the Department of Transportation authority to regulate commercial spaceflight, including commercial launch services; required the government to assume responsibility for large third-party damages that could arise from U.S. commercial space activities; and laid the foundation for future regulation of commercial human spaceflight.[34]

The **U.S. Commercial Space Launch Competitiveness Act** of 2015 extended the moratorium until 2023 on regulation of commercial human spaceflight activities, which has since been extended to early 2025. The law also explicitly allowed U.S. citizens and companies to own and sell any resources extracted from bodies in space, such as asteroids and the Moon, permitting them to "facilitate commercial exploration for and commercial recovery of space resources." The text also states that the United States, in accordance with the Outer Space Treaty, cannot use this law to "assert sovereignty or sovereign or exclusive rights or jurisdiction over, or the ownership of, any celestial body."[35] Notably, the United Arab Emirates (UAE), Luxembourg, and Japan have all enacted similar laws that allow the ownership and transfer of ownership of space resources.[36]

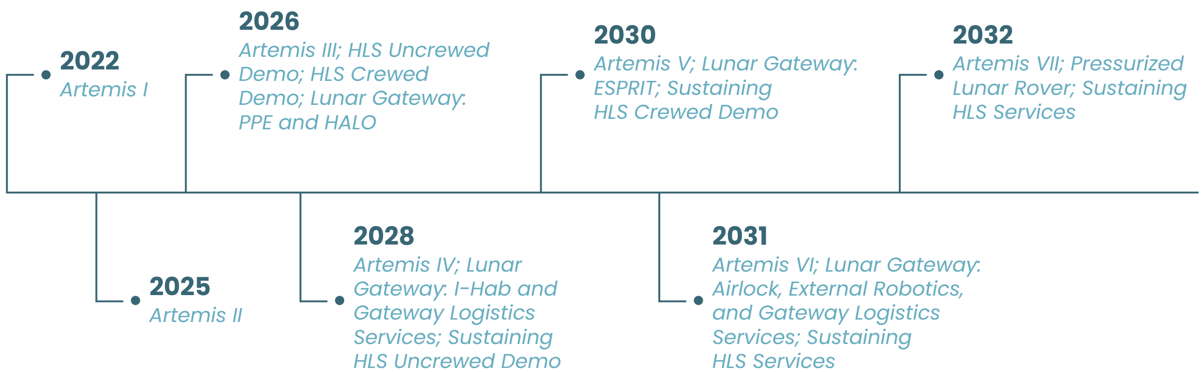
Regulations

Today, the U.S. government regulates elements of every private U.S. space activity.[37] The Department of Transportation oversees private spaceports and licenses launch and reentry of spacecraft, requiring information about the space payload as part of the licensing process. The FCC licenses spectrum use and imposes associated requirements regarding space sustainability on licensees. Any satellite or spacecraft wishing to broadcast radio frequencies to or from any territory of the United States must receive a license from the FCC, including foreign satellites seeking to serve the U.S. market. The Department of Commerce licenses remote-sensing satellites, including ones conducting non-Earth imaging, such as imaging of other satellites in space.

Beyond these regulations, the United States is considering proposals to regulate novel private sector space activities, a process often referred to as "mission authorization."[38] These novel activities include commercial habitats, in-space manufacturing, and on-orbit refueling, none of which are clearly addressed by existing licensing schemes.

Figure 4: NASA Crewed Lunar Missions Milestone Timeline

Source: "Fiscal Year 2025 Budget Request," NASA, last updated August 29, 2024, https://www.nasa.gov/fy-2025-budget-request/.



Activities

To date and for the foreseeable future, the majority of U.S. missions that transit cislunar space, reach lunar orbit, or land on the Moon are directly or indirectly funded by NASA and focus on space exploration. Today, most NASA funding for cislunar missions supports the Artemis program, an initiative to reestablish a human presence and build a long-term base on the Moon, as well as lay the foundations for a future crewed mission to Mars.[39] According to NASA, the goals of the Artemis program are to make new scientific discoveries, realize economic benefits from returning to the Moon, and inspire a new generation of explorers.[40]

Achieving those goals will come at a high cost. According to the NASA Office of Inspector General, the agency will have spent approximately $93 billion on the Artemis program (including work on the Space Launch System) between 2012 and 2025.[41] In 2022, NASA launched the uncrewed Artemis I mission, which placed the Orion capsule into lunar orbit and returned the craft to Earth.[42] The first crewed Artemis mission, Artemis II, will take four astronauts into Earth orbit and a free-return trajectory around the Moon no earlier than 2025.[43] The subsequent Artemis III mission, planned for no earlier than 2026, will take astronauts to the lunar surface and target a landing site near the Moon's south pole.[44]

In addition to facilitating the Artemis program's second human landing on the Moon, the third crewed Artemis mission, Artemis IV, will dock with the Lunar Gateway, a planned space station that will provide habitation space for astronauts and serve as a communications hub and science laboratory.[45] NASA plans for the station to use a near-rectilinear halo orbit (NRHO) associated with the Earth–Moon L_2 Lagrange point.[46] In-space assembly of the Lunar Gateway is planned to start in 2028.[47] NASA is collaborating with ESA, the Canadian Space Agency, the Japan Aerospace Exploration Agency (JAXA), the UAE, and commercial partners on the project.[48] Planned for no earlier than 2030 and 2031, respectively, Artemis V and VI will also complete lunar landings and continue efforts to construct the Lunar Gateway.[49]

To enhance its Deep Space Network to support upcoming lunar missions, NASA is building and expanding a network of Lunar Exploration Ground Sites (LEGS) so the agency can remain in continuous communications with the Moon during its orbit around Earth.[50] NASA is also developing the LunaNet framework and Lunar Communications Relay and Navigation Systems (LCRNS) project to enable cislunar networking and connectivity services.[51]

In addition to the Artemis program, NASA is currently funding missions to the Moon as part of the CLPS program, an initiative through which the agency contracts with companies to deliver freight to the lunar surface.[52] Two CLPS awardees, Astrobotic and Intuitive Machines, have already sent commercial spacecraft to the Moon carrying NASA payloads. While the Astrobotic spacecraft suffered a malfunction en route and was not able to complete its mission, the Intuitive Machines spacecraft touched down on the Moon in February 2024, completing the world's first successful commercial lunar landing. Currently, NASA has several CLPS contracts (i.e., trips to the Moon) on the books to deliver payloads to the lunar surface. Many NASA payloads planned for CLPS missions were built through the Lunar Surface Instrument and Technology Payloads (LSITP) program.[53]

Focused on planetary exploration, NASA's Small Innovative Missions for Planetary Exploration (SIMPLEx) program is also funding missions to the Moon. The aim of SIMPLEx is to build small, low-cost spacecraft for launches as secondary payloads on other missions. For example, a SIMPLEx mission called LunaH-Map was launched on Artemis I in 2022.[54] Though the LunaH-Map mission experienced propulsion problems after deployment, it did conduct a lunar flyby and returned some data to Earth. The only other SIMPLEx mission to the Moon, a lunar orbiter called Lunar Trailblazer, is currently scheduled to launch in 2025.[55]

The DoD is also funding work related to cislunar space. Specifically, the Defense Advanced Research Projects Agency (DARPA) is leading a project that aims to move large payloads in cislunar space using a nuclear thermal rocket (NTR). The Demonstration Rocket for Agile Cislunar Operations (DRACO) program will produce a baseline design for the NTR reactor, build the reactor, and launch it into space to conduct experiments on the technologies in orbit.[56] The DRACO flight experiment could take place as soon as 2027. DARPA is also funding the 10-Year Lunar Architecture (LunA-10) Capability Study, through which 14 companies are proposing architectures for future lunar infrastructure.[57] Initial study results were presented in June 2024.[58]

Additionally, the Air Force Research Laboratory (AFRL) is developing two satellites, Oracle-Mobility and Oracle-Prime, designed to provide SSA information on objects in cislunar space.[59] The Oracle-Mobility satellite will test new navigational techniques needed for cislunar operations and object tracking and is expected to launch no earlier than 2025. Applying lessons learned from the Oracle-Mobility mission, the Oracle-Prime satellite will operate in a halo orbit associated with the Earth–Moon L_1 Lagrange point and test techniques to monitor space objects that transit cislunar space.

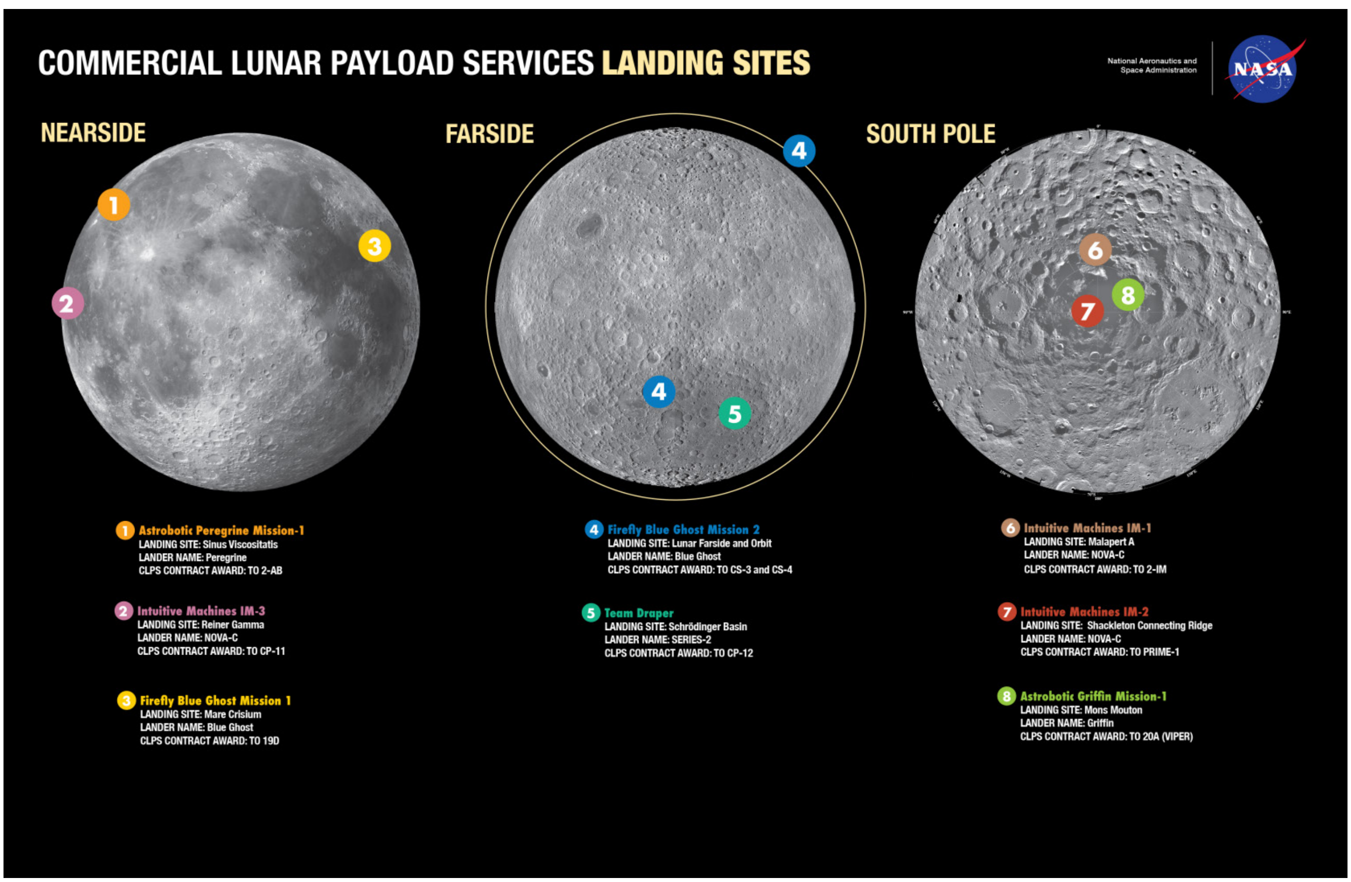
There are also several U.S. companies attempting to build and launch missions to the Moon for commercial purposes. For example, Astrolab is developing the Flexible Logistics and Exploration (FLEX) lunar rover, which will be launched on SpaceX's Starship rocket. Astrolab has agreements from eight customers to carry commercial payloads on the rover to the Moon's surface in 2026.[60]

Australia

In partnership with NASA, Australia plans to build and send a rover to the surface of the Moon on an upcoming Artemis mission, perhaps as early as 2026.[61] Support for the development of the rover comes in part from Australia's Moon to Mars initiative, which awards grants to Australian space companies, aiming to grow the country's space economy and give it a greater role in future missions to the Moon. Moon to Mars additionally funded the development of scientific instruments to be used for other U.S.-led lunar

Figure 5: Commercial Lunar Payload Services Landing Sites

Source: "Commercial Lunar Payload Services (CLPS) Deliveries," NASA, https://science.nasa.gov/lunar-science/clps-deliveries/.



missions.[62] However, Australia does not currently have an agreement with the United States to send an Australian astronaut to the Moon as part of the Artemis program.

Canada

The Canadian Space Agency has two programs focused on the Moon: the Lunar Exploration Accelerator Program (LEAP), which manages the science, technology, and commercial lunar payloads opportunities for Canadian industry and academic partners, and Canadarm3, a robotic arm built by Canadian company MDA Space that will be installed on the Lunar Gateway to manipulate and maneuver objects on the exterior of the station.[63] Canadarm3 will perform a similar role to the first Canadarm, used on the Space Shuttle orbiter, and Canadarm2, currently installed on the International Space Station (ISS). In return for supplying Canadarm3, NASA offered Canada the opportunity to send science, technology, and commercial lunar payloads and fly two Canadian astronauts to the Moon on Artemis missions.[64]

China

In 2004, China announced the Chinese Lunar Exploration Program (CLEP)—also known as the Chang'e Project—which would consist of a series of robotic lunar missions built and operated by the China National Space Administration. As originally envisioned, China planned for eight Chang'e missions, six of which have been completed. The series of Chang'e missions has operated lunar landers, rovers, orbiters, and sample-return activities.[65] In 2024, China's most recent CLEP mission, Chang'e 6, successfully landed on the Moon's south pole and returned a sample of the lunar regolith (a layer of loose, dust-like material that covers the Moon's surface). The last two missions, Chang'e 7 and Chang'e 8, are expected to launch in 2026 and 2028, respectively. Chang'e 8 will test technologies required to build a permanent base and could be powered by nuclear technology. Both missions would land in the lunar south pole.[66]

In July 2023, China declared that crewed missions would be added to CLEP, with a crewed landing on the lunar surface planned for 2030.[67] Separately, China also announced plans in 2019 for a future scientific research station to be constructed within the next 10 years at the Moon's south pole. This vision has likely evolved into the planned International Lunar Research Station (ILRS), a joint venture between China and Russia announced in 2021.[68] At least 10 additional countries have signed up to support the ILRS, including Venezuela, Belarus, Pakistan, Azerbaijan, South Africa, Egypt, Nicaragua, Thailand, Serbia, and Kazakhstan.[69] China is also planning a GPS-like constellation for lunar orbit that will provide satellite navigation for the Moon.[70] To recruit international partners for its crewed research station, China announced the creation of the International Lunar Research Station Cooperation Organization (ILRSCO) in 2023.[71]

China is currently operating the Queqiao 1 relay satellite in a halo orbit associated with the Earth–Moon L_2 Lagrange point, providing communications for China's missions to the side of the Moon not facing Earth.[72] Operating in a frozen elliptical orbit around the Moon, the Queqiao 2 satellite also serves as a communications relay for lunar missions.[73]

SAMPLE RETURN	MISSION NAME	MISSION TYPE
2007	Chang'e 1	Orbiter
2010	Chang'e 2	Orbiter
2013	Chang'e 3	Lander and Rover
2014	Chang'e 5-T1	Sample-Return Demo and Testing
2018	Chang'e 4	Communications Relay Satellite, Lander, and Rover
2019	Chang'e 5	Sample-Return
2024	Chang'e 6	Sample-Return
2026	Chang'e 7	Orbiter, Lander, Hopping Probe, and Rover
2028	Chang'e 8	Lander, Rover, and Prospecting Robot

Figure 6: Chang'e Timeline

Source: David R. Williams, "Future Chinese Lunar Missions," NASA, https://nssdc.gsfc.nasa.gov/planetary/lunar/cnsa_moon_future.html.

In June 2024, China released a road map for a series of projects aimed at building lunar infrastructure, including elements related to communications and SSA, as well as GPS-equivalent services for lunar and deep-space users.[74]

Europe

Through ESA, Europe is closely involved in NASA's Artemis missions. Most notably, ESA produces the European Service Module (ESM) for the Orion crewed capsule.[75] Already tested on Artemis I, the ESM will be used on all Artemis missions.[76] In addition, ESA will be providing several components for the Lunar Gateway, specifically a habitation module, a refueling and storage module, and a module that will contain communications equipment for linking with the lunar surface and satellites in lunar orbit.[77] In return for these contributions, ESA will be able to send two European astronauts to the Moon as part of the Artemis program.

ESA is also designing Argonaut, a lunar lander that can perform a variety of different missions. Argonaut will be able to carry cargo such as scientific payloads, power-generation and -storage equipment, and lunar rovers to the Moon's surface. Currently, ESA is planning to use the Ariane 6 rocket to launch Argonaut missions.[78]

To support Artemis, Argonaut, and other lunar missions, ESA established a program called Moonlight to provide PNT services for the Moon, as well as communication and data relay services between the Earth and Moon. Currently scheduled to launch in 2026, the Lunar Pathfinder is the first spacecraft developed as part of this initiative. The satellite will orbit the Moon, communicating with Earth using an X-band link and with missions on the Moon using S-band and ultra-high frequency links.[79] It will be launched with the CLPS Blue Ghost M2.[80]

India

In August 2023, India became the fourth nation to successfully land on the Moon, landing the Chandrayaan-3 probe in the lunar south pole region.[81] India is working with Japan on the Lunar Polar Exploration (LUPEX) mission, expected to be launched no earlier than 2025. Japan agreed to provide the rover and launcher for LUPEX, while India agreed to provide the mission's lander.[82] Additionally, India is in the early stages of planning its Chandrayaan-4 mission with the aim of returning a sample of lunar regolith to Earth.[83]

Israel

In 2019, two private entities from Israel—SpaceIL and Israel Aerospace Industries—launched the Beresheet lunar lander, the first privately funded attempt to reach the Moon. The lander ultimately crashed into the Moon after its gyroscopes failed on approach to the landing site.[84] SpaceIL announced plans in 2020 to build a second Beresheet lander for launch in 2024, but there is no public indication of subsequent progress on this mission.[85] Israel Aerospace Industries is also partnering with OHB SE, a German aerospace technologies group, on the Lunar Surface Access Service (LSAS) program, which supports commercial lunar payload delivery. The first LSAS mission is planned for 2025.[86]

Japan

Japan has maintained an active lunar exploration program for over 30 years. In 1990, it sent the Hiten spacecraft to the Moon, making it the third country after the Soviet Union and United States to launch a lunar mission. Japan did not send another spacecraft to the Moon until 2007, when it launched the SELENE mission, also called Kaguya, composed of three separate spacecraft: a main orbiter, a relay satellite, and another satellite designed to map the Moon's gravity field.[87]

Japan's most recent lunar mission was the Smart Lander for Investigating Moon (SLIM), designed to demonstrate precision lunar landings.[88] As it descended to the lunar surface in January 2024, SLIM successfully deployed two lunar landers. Unfortunately, the lander touched down with its solar arrays misoriented away from the Sun, which meant that it could not generate the amount of power required for normal operations. Even in this state, SLIM survived several lunar nights—but has not communicated with ground controllers on Earth since April 2024.[89]

Japan has several missions planned over the next few years. This includes the Hakuto-R 2 mission, planned by Japanese company ispace scheduled for late 2024, which will carry a lunar lander and micro rover.[90] Toyota and JAXA are currently developing a crewed, pressurized lunar rover that will be flown to the Moon on a future Artemis mission.[91] As part of the NASA CLPS initiative, the Japanese company Dymon is also planning to launch a lunar rover called Yaoki on an upcoming Intuitive Machines mission to demonstrate its ability to support future NASA missions.[92] Additionally, Japan will cooperate with India on the aforementioned joint LUPEX mission.

As part of the Artemis program, Washington and Tokyo signed an agreement in April 2024 for a Japanese astronaut to be the first non-U.S. national to crew an Artemis mission to the lunar surface.[93]

Russia

Russia's most recent mission to the Moon, the uncrewed Luna 25 lunar lander, failed when the probe crashed into the Moon's surface in 2023.[94] Several more Luna missions are in various stages of planning and development, with some scheduled for launch in the next five years. These upcoming uncrewed missions are part of the Luna-Glob program, which aims to create a fully robotic lunar base based on plans from 1997. This program would set the stage for later crewed missions to the Moon.[95]

Planned for launch in 2027, the lunar orbiter Luna 26 is the next Russian mission to the Moon. It will carry a scientific payload, as well as serve as a communications relay between the

Moon and Earth. In 2019, Beijing and Moscow agreed to cooperate on both Russia's Luna 26 mission and China's Chang'e 7 mission.[96] Originally, ESA had also intended to collaborate with Russia on Luna 26; however, following Russia's invasion of Ukraine in 2022, the agency canceled these plans and withdrew from work with Russia on the Luna 27 mission, a lander planned for the lunar south pole.[97] Russia has claimed it will complete Luna 26 and Luna 27 independently, with the latter consisting of a primary mission (Luna 27a) and a backup (Luna 27b) in the event Luna 27a fails.[98]

As early as 2009, Russia had been planning a new, reusable, crewed space capsule for use in low Earth orbit (LEO) and for transportation to the Moon. This new Orel spacecraft would be designed to transport up to four humans. In 2020, Russian officials announced plans for an uncrewed test launch of Orel in 2023 that never happened.[99] Russia also said it was planning an uncrewed mission to the Moon in 2028, but there are no signs that it remains on track to meet this goal. And although it announced in 2007 that it aimed to field its own Lunar Orbital Station, there has been no subsequent indication of work on its development.[100]

Given budget constraints—and the failure of Luna 25 in 2023—it is unlikely that Russia will be able to launch any of these proposed missions. Sanctions imposed on Russia since its invasion of Ukraine have severely limited its access to Western technologies and microelectronics, further stalling Russian efforts to start or continue work on future Moon missions.

> *Given budget constraints—and the failure of Luna 25 in 2023—it is unlikely that Russia will be able to launch any of these proposed missions.*

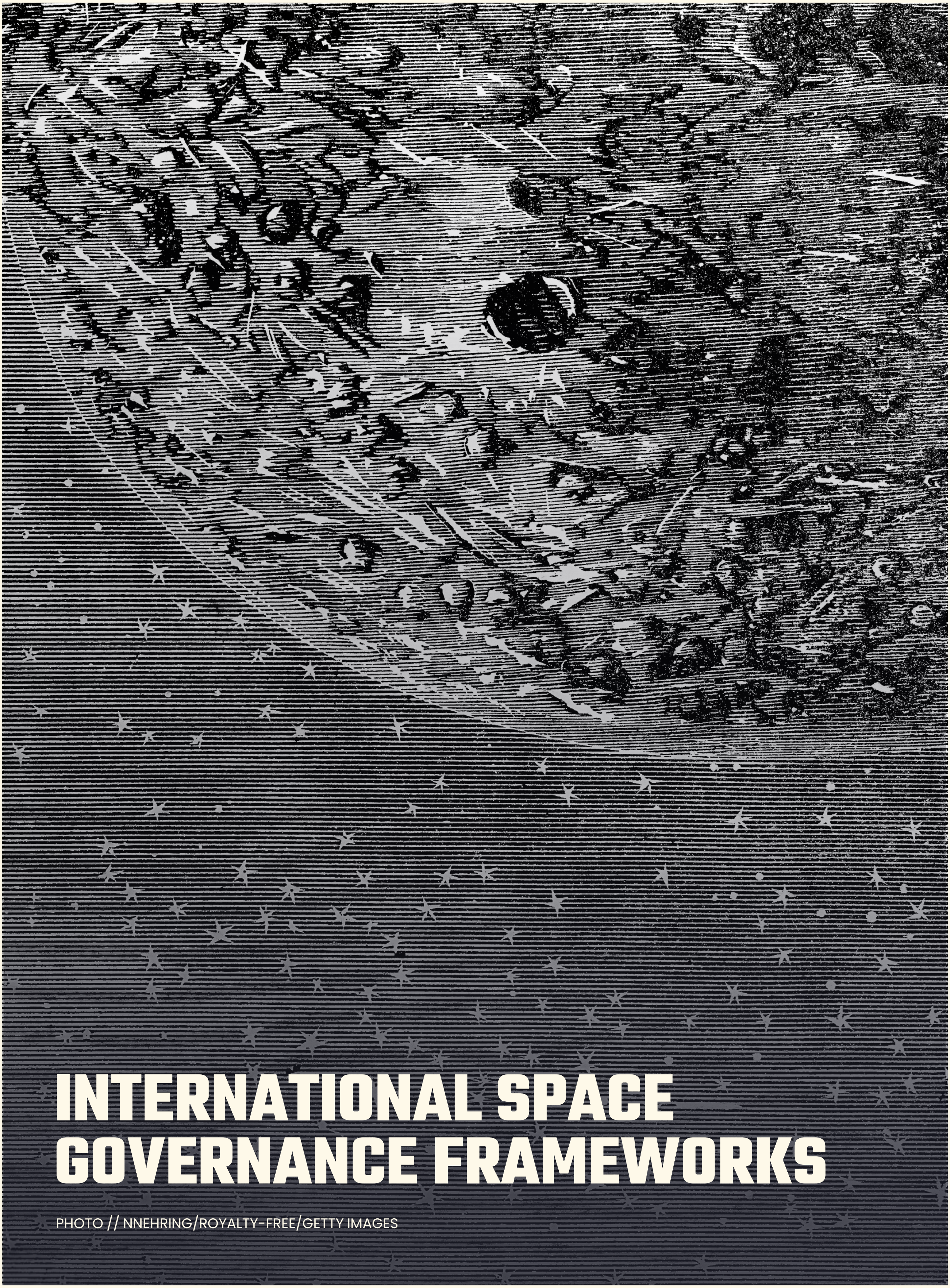
South Korea

Launched in 2022, the Korea Pathfinder Lunar Orbiter (KPLO), also known as Danuri, is South Korea's first spacecraft to operate beyond geostationary Earth orbit (GEO). The KPLO was designed to survey the lunar surface and help identify possible landing sites for future missions. It is currently orbiting the Moon.[101] The South Korean space agency is planning an uncrewed mission to the lunar surface in 2032 and actively participates in UN discussions on lunar norms and sustainability.[102]

Other Countries

Additional countries have flown payloads on another nation's lunar missions in the past several years or have plans to do so in the next decade. For example, the UAE is sponsoring an experiment created by students at AGH University of Science and Technology in Poland for inclusion as a rideshare payload on an upcoming Astrobotic CLPS mission.[103] The UAE also developed a lunar rover that flew aboard ispace's Hakuto-R 1 mission but was lost in the lander's crash.[104] Following the crash, Prime Minister and Vice President Sheikh Mohammed bin Rashid Al Maktoum signaled that the country will make another attempt at a lunar landing.[105] Additionally, the UAE has other lunar plans, providing an airlock for the Lunar Gateway and making the UAE the only non-ISS partner nation providing hardware for the new station.[106]

Similarly, in May 2024, Pakistan sent the iCube Qamar, a CubeSat designed to orbit the Moon and take photos of the lunar surface, as a payload on board China's Chang'e 6 mission.[107] In 2022, Mexico initiated its Colmena project, an effort to promote Mexican participation in lunar exploration through the development of microrobots, five of which were launched aboard Astrobotic's Peregrine 1 mission.[108] While the mission's failure destroyed the payload, a second Colmena mission is slated for 2027.[109] Turkey is planning on launching its lunar orbiter AYAP 1 in 2026, followed by AYAP 2, which aims to land a rover on the Moon in 2028.[110] Finally, New Zealand plans to conduct SSA research and create a cislunar SSA capability in partnership with NASA.[111]



INTERNATIONAL SPACE GOVERNANCE FRAMEWORKS

PHOTO // NNEHRING/ROYALTY-FREE/GETTY IMAGES

There are several space-specific international treaties and other international agreements that address space issues, as well as the U.S.-led Artemis Accords. While no treaty deals solely with cislunar space, the provisions of the space-specific agreements cover cislunar space no differently than any other domain.

THE OUTER SPACE TREATY AND RELATED AGREEMENTS

Evolving from several arms control resolutions debated in the United Nations during 1966, the **Outer Space Treaty (OST)** of 1967 was the first international treaty concerning space.[112] It serves as the foundation for international space law and addresses all government and private sector space activities carried out by parties to the treaty. Although the treaty does not reference cislunar space, it does specifically reference the Moon—and thus, due to its broad applicability to all space activities, does apply to cislunar space.

There are currently 114 parties to the OST, including all major spacefaring nations.[113] Key provisions of the treaty state that

- "the exploration and use of outer space . . . shall be carried out for the benefit and in the interests of all countries . . . and shall be the province of all mankind";
- outer space shall be "free for exploration and use by all States";
- outer space is "not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means";
- states shall not place nuclear weapons or other weapons of mass destruction in orbit or on celestial bodies, or "station such weapons in outer space";
- "the moon and other celestial bodies shall be used . . . exclusively for peaceful purposes," with no weapons testing of any kind, military maneuvers, or the establishment of military bases;
- astronauts shall be regarded "as envoys of mankind";
- states shall be responsible for national space activities, whether carried out by "governmental agencies or by non-governmental entities";
- states shall be liable for damage caused by their space objects; and
- states shall avoid "harmful contamination" of space and celestial bodies.[114]

The Committee on the Peaceful Uses of Outer Space (COPUOS), which played a key role in creating the OST, was originally established by the UN General Assembly in 1958 as an ad hoc committee that became a permanent body in 1959 tasked with addressing the exploration and use of space for the benefit of all humanity.[115] The UN Office for Outer Space Affairs (UNOOSA) acts as the secretariat for COPUOS, helping to implement space treaties and General Assembly resolutions that form the basis of international space law.[116]

Other than the OST, there are four other legally binding international agreements that govern space. Each applies to spacecraft, people, and activities in cislunar space.

The **Rescue Agreement** of 1968 requires that parties to the agreement provide assistance, when possible, to spacecraft personnel in distress or in the event of an accident or emergency landing. Additionally, should a party to the agreement become aware of spacecraft personnel in distress, they are required to notify the launching nation and the UN secretary general. The agreement also permits nations to request assistance recovering their space objects that land in territories outside of their jurisdiction. The launching nation is required to cover any costs incurred during recovery efforts.[117]

The **Liability Convention** of 1972 states that countries are liable for any damages incurred from all space objects launched from their territories.[118] The crash of a nuclear-powered Soviet satellite onto Canadian territory in 1978 resulted in the only claim to date made under this convention.

The **Registration Convention** of 1976 requires that states submit details to the United Nations about their spacecraft and satellites launched into space. The associated UN registry of space objects contains information such as the name of the launching nation, an appropriate designator of the space object or its registration number, date and location of launch, basic orbital parameters, and general function of the space object.[119]

Though most of the **Moon Agreement** of 1984 merely reemphasizes provisions of the OST, it also includes new language specifying that the Moon is "the common heritage of mankind" and providing clarity on the use of lunar resources. The treaty specifies that all references to the Moon also apply to all other celestial bodies in the Solar System, including orbits and trajectories to, from, and around them. Regarding the lawful use of lunar resources, the treaty planned to establish an international regime to administer the exploitation of resources on the Moon, other planets, asteroids, and any of the Solar System's other celestial bodies.[120] The regime was never implemented because there are only 17 parties to the treaty as of October 2024.[121] The Moon Agreement has had little impact on international space law, as most spacefaring nations, including the United States, Russia, and China, decided not to sign it.

In addition to these five legally binding international space agreements, UNOOSA often highlights five non-binding resolutions approved by the General Assembly that articulate key principles of international space law. The earliest of these resolutions is the Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space, which predates the OST and was passed in 1963. The other resolutions, passed in the 1980s and 1990s, present principles for international television broadcasting from satellites, remote sensing of Earth from space, and nuclear power sources in space, as well as a declaration on the importance of international cooperation in space for the benefit of all people, with a particular focus on developing nations.[122]

In 2010, COPUOS established the Working Group on the Long-term Sustainability of Outer Space Activities to identify issues impacting space sustainability—such as space debris, SSA, space weather, and national regulatory regimes for space—and develop ideas and voluntary guidelines to improve them. In 2019, COPUOS adopted a set of 21 voluntary best-practice guidelines for long-term sustainability that had been negotiated and approved by the working group.[123]

To address the use of space resources, including those on the Moon, the legal subcommittee of COPUOS also created the Working Group on Legal Aspects of Space Resource Activities in 2022, giving it a five-year mandate to examine the benefits of establishing a framework for use of space resources and whether such a framework might require new international agreements.[124] Establishment of this working group represents a consensus view of COPUOS members that the OST does not adequately address the issue of space resource use and denotes members' willingness to consider new international instruments to tackle it.[125]

Finally, during their official annual meetings in June 2024, COPUOS members agreed to establish the Action Team on Lunar Activities Consultation (ATLAC), which aims to provide recommendations for international consultative mechanisms on sharing information and best practices, ensuring safety, facilitating interoperability for lunar activities, protecting the lunar environment, and mitigating the creation of debris in lunar orbit. ATLAC membership is open to any COPUOS member, though key participants will include the United States and China.[126] One expert involved in the establishment of the action team noted to this report's authors that it was designed to facilitate such discussions between the United States, China, and Russia on lunar governance and coordination.[127] The group will share its final recommendations during COPUOS meetings in 2027.

While not directly related to cislunar space or the Moon, it is worth noting that UNOOSA supports the work of the International Committee on Global Navigation Satellite Systems (ICG). The ICG serves as a coordinating body for operators of such systems, working to facilitate compatibility, interoperability, communications, and transparency to benefit all global users of PNT services.[128]

THE INTERNATIONAL TELECOMMUNICATION UNION

Originally established by the International Telegraph Convention of 1865, the International Telecommunication Union (ITU) is now a UN agency responsible for issues pertaining to information and communications technologies. Most of its mission is focused on Earth, but a key part of its responsibilities relates to the space environment. The ITU is responsible for international coordination of radio spectrum use, including spectrum used by satellites. It facilitates international coordination of spectrum use for spacecraft orbiting Earth—meaning the ITU has effectively had a regulatory role for most spacecraft, since every crewed and uncrewed spacecraft in orbit since Sputnik 1 in 1957 has relied on radio communications.[129]

The ITU groups satellites orbiting Earth into two categories: GEO, also called GSO, or non-geostationary orbit (non-GSO). Due to the finite space for satellites in GEO—sometimes compared to beachfront property on Earth—the ITU has developed rules that balance the access of all nations to these valuable slots and approval of new systems on a first-come, first-served basis.[130]

To date, there are very few ITU rules or decisions that relate specifically to cislunar space or the Moon. The union's first foray into regulating spectrum use in cislunar space happened in 1971, when it added a provision to the Radio Regulations, the ITU's legally binding spectrum rules, limiting the potential for interference to radio astronomy in the shielded zone of the Moon (SZM). The SZM is defined as the lunar surface area and adjacent part of space that are shielded from emissions originating from within 100,000 kilometers of Earth's center (i.e., the far side of the Moon). The rule was designed to keep this naturally quiet zone free from human-made radio-signal interference so that the SZM could be used for radio astronomy in the future.[131]

Since then, the ITU has not promulgated additional formal rules focused on cislunar space or the Moon. In 1997, it urged members to carefully assess the impacts of communications relay systems between the Earth and Moon. More recently, attendees at the 2023 World Radio Conference, a gathering organized by the ITU every three to four years to update the Radio Regulations, approved studies to look at frequency bands for lunar and cislunar communications.[132] The results of the studies will be presented and debated at the 2027 conference.

THE ARTEMIS ACCORDS

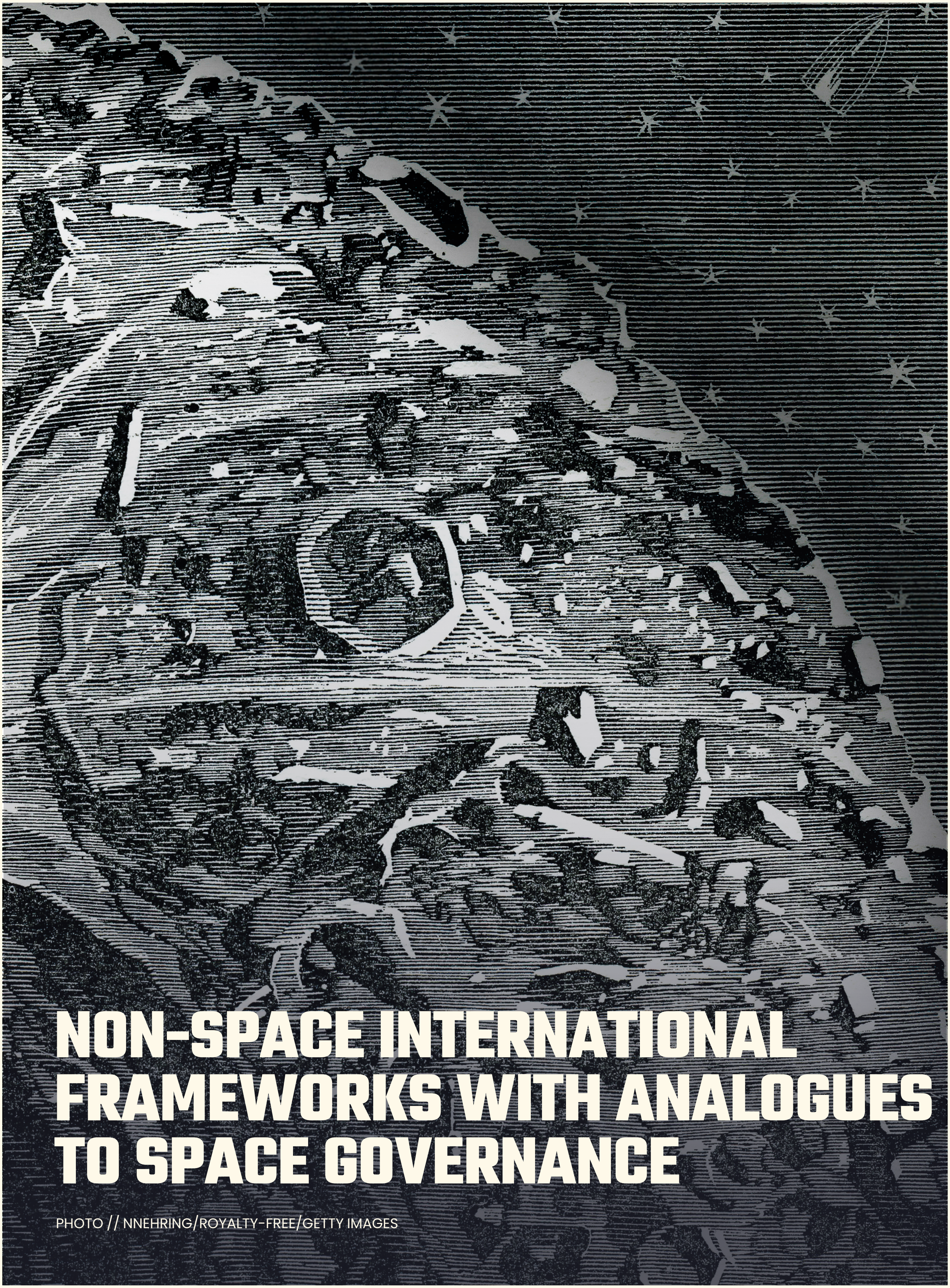
The Artemis Accords are non-binding multilateral agreements between the United States and 43 other countries that contain various provisions related to norms of behavior in space. The United States has stated that these accords are intended to help facilitate operational implementation of obligations derived from the OST and other international space agreements.[133]

The Artemis Accords established new norms among signatories aimed at improving the transparency, peacefulness, and interoperability of space activities. Among other commitments, signatories agree to release scientific information gathered through civil space exploration to the public and other Artemis signatories; make reasonable efforts to adhere to existing interoperability standards for space infrastructure; protect space sites considered significant to human heritage; and prevent the accumulation of orbital debris around the Moon.[134]

Though legal experts continue to disagree on the meaning of OST language related to using space resources, the Artemis Accords assert that the extraction and utilization of space resources can be done without violating the OST.[135] Specifically, they state that the use of space "does not inherently constitute national appropriation under Article II" of the OST. Furthermore, they call for the development of international practices and rules governing the extraction and use of space resources.[136]

The Artemis Accords are the first international agreement to implement a concept referred to as "safety zones," which are designed to prevent the activities of one nation from causing harmful interference to the activities of other countries—for example, to or by lunar launch and landing sites. Both launches and landings on the Moon's surface create plumes of regolith and debris, which may damage or blind nearby spacecraft. Artemis signatories are expected to notify and coordinate with the creators of safety zones before conducting space activities within these areas. However, some experts have suggested safety zones may constitute "national appropriation" in violation of Article II of the OST.[137] But it can be noted that international maritime law does provide precedent for safety zones, albeit in a different domain.[138]

Russia has criticized various elements of the Artemis Accords for being U.S.-centric. China has said the accords reinforce competition rather than cooperation in space. Neither nation has signed the Artemis Accords nor signaled an interest in supporting the Artemis program.[139] Conversely, there is no indication that the United States would collaborate with China or Russia on the ILRS. China suggested during a presentation at the International Astronautical Congress in 2023 that the ILRS framework would eventually include space sustainability principles akin to the Artemis Accords.[140]



NON-SPACE INTERNATIONAL FRAMEWORKS WITH ANALOGUES TO SPACE GOVERNANCE

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There are several domains on Earth that have similar jurisdictional characteristics as space, including Antarctica, the Arctic, the high seas, and international airspace. Each of these areas possesses its own established international governance mechanisms, which can provide lessons for future space governance frameworks and evolutions of current international space law. This section provides an overview of these non-space agreements and frameworks, and the subsequent section draws parallels to space governance and identifies lessons that could be used to help address associated gaps.

THE LAW OF THE SEA TREATY

Signed in 1982, the UN Convention on the Law of the Sea (UNCLOS), also called the "Law of the Sea Treaty," established the international legal framework for maritime activities and uses of ocean resources. Key provisions of the treaty include granting nations the right to assert sovereignty up to 12 nautical miles from shore, giving all states freedom of navigation and overflight of the high seas, and setting up rules for exploring and exploiting sea-floor resources.[141] Currently, 167 parties and the European Union have ratified the treaty—with the notable exception of the United States, which has cited concerns that treaty provisions on the use of seabed resources were not free-market friendly.[142]

Established in 1994 in accordance with UNCLOS provisions, the International Seabed Authority (ISA) authorizes and controls seabed mineral extraction and works to protect the seafloor environment. To justify such regulation, UNCLOS asserts that ocean resources, outside of those under national jurisdiction, are the "common heritage of mankind." The work and policies of the ISA are governed by an assembly made up by representatives of all parties to UNCLOS, a 36-person council elected by the assembly, and a secretary-general elected by the assembly for a four-year term.[143] To date, it has authorized over 30 seabed mining-exploration contracts.[144] As the ISA has not yet finalized regulations for commercial mining, held up by calls for a global moratorium due to alleged environmental impacts, it has yet to issue any approvals for commercial deep-sea mining projects.[145]

At the same time as the original UNCLOS negotiations in the 1980s, the United States enacted the Deep Seabed Hard Minerals Resources Act to provide a licensing framework for U.S. companies wanting to mine the seafloor.[146] Though the United States has issued licenses for seafloor mining, some experts argue that U.S. companies could face international legal risks should they begin commercial mining without ISA approval.[147]

THE ANTARCTIC TREATY AND ANTARCTIC TREATY SYSTEM

Antarctica is the only continent without an indigenous human population. No human is believed to have seen Antarctica or its ice shelf until 1820.[148] Since that first sighting, seven countries have made territorial claims on the continent, with some national claims overlapping with others. The Cold War added another dimension to the geopolitics of Antarctica: though neither the United States nor the Soviet Union made territorial claims, both operated research stations there. Additionally, neither saw Antarctica as having strategic military value, with both nations seeking to prevent the militarization of the continent.[149]

Though some claimant nations to territory on Antarctica initially objected, the United States pursued the development of and eventually succeeded in establishing an international treaty that preserved the freedom of scientific research and peaceful use of the continent without adjudicating or deciding on any territorial claims. Convened by the United States in 1958, the Antarctic Conference, which produced the Antarctic Treaty, only included the 12 nations with contemporary scientific equities in Antarctica during the International Geophysical Year (IGY) of 1957 to 1958.[150] Signed in 1959, the Antarctic Treaty serves as the foundation for a system of treaties and agreements that today provide the international governance framework for the continent.[151]

As part of the treaty framework, signatories began meeting regularly to discuss issues related to Antarctica, such as environmental protection and cooperation on research. Officially called the Antarctic Treaty Consultative Meeting (ATCM) process, these meetings now occur each year, and participants make decisions by consensus. These annual meetings have provided opportunities for treaty Consultative Parties to develop specific, legally binding agreements, with greater precision than the original treaty on rules covering specific activities in Antarctica.[152] The ATCM process has also been a mechanism for treaty parties to update and address contemporary issues that were not foreseen at the time the treaty was drafted.

Currently, key legally binding documents of the Antarctic Treaty System include the original 1959 treaty, the Protocol on Environmental Protection to the Antarctic Treaty, the Convention on the Conservation of Antarctic Marine Living Resources, and the Convention for the Conservation of Antarctic Seals.[153] These documents and resolutions, decisions, recommendations, and other measures adopted by past ATCMs cover many topics, such as peaceful use and scientific collaboration, environmental protections, preservation of historic sites, management of tourism, designation and management of protected areas, mapping, safety, information sharing, logistical cooperation, and weather and meteorological cooperation.[154]

Since 1998, commercial mining in Antarctica has been prohibited. Prior to this ban, several treaty parties had been working on a treaty addendum that would have regulated future resource extraction. Growing concerns about impacts of human activities to Earth, not just in Antarctica but around the world, and the rise of the environmental movement in the 1980s led to the abandonment of the addendum.[155] At that time, Australia and France initiated efforts to oppose plans to allow future mining. Even today, there is limited interest in Antarctic mining, as experts question its business viability.

THE INTERNATIONAL REGULATIONS FOR PREVENTING COLLISIONS AT SEA

Until the 1860s, most maritime nations developed and used their own navigation rules and practices.[156] In 1863, the United Kingdom and France agreed on a set of maritime rules that were eventually adopted by 30 countries, including the United States. A well-known guide to these regulations, published in 1867 by British official Thomas Gray, was called *The Rule of the Road*, the progenitor of all future references to such guidelines as "rules of the road."[157] To expand on these regulations, the United States convened the first International Maritime Conference in 1889 to discuss additional measures needed to prevent maritime collisions.[158] Throughout the next 70 years, a regular cadence of major international maritime conferences updated and revised these rules.

Then in 1972, all contemporary international navigation and maritime rules were replaced entirely by the International Regulations for Preventing Collisions at Sea, also known as Collision Regulations (COLREGs), which specify the rules of the road for ships at sea with the aim of preventing accidents.[159] The COLREGs are published and maintained by the International Maritime Organization (IMO), a UN agency established in 1948 that focuses on ensuring safety at sea. Nations become a member of the IMO by ratifying the Convention on the International Maritime Organization, whereupon they are required to enact the COLREGs as national law within their own jurisdictions.[160]

THE ARCTIC COUNCIL

The Arctic Council is an intergovernmental forum established in 1996 to promote cooperation, coordination, and engagement between countries with territory in the Arctic. Only nations with Arctic territory—Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, and the United States—are members of the council, though representatives of Indigenous peoples can join as permanent participants. Additionally, non-Arctic nations can be admitted as observers. Senior officials representing each member nation convene every six months to discuss past accomplishments and future work of the council, as well as issue a nonbinding declaration. Every two years, the council holds ministerial-level meetings.[161]

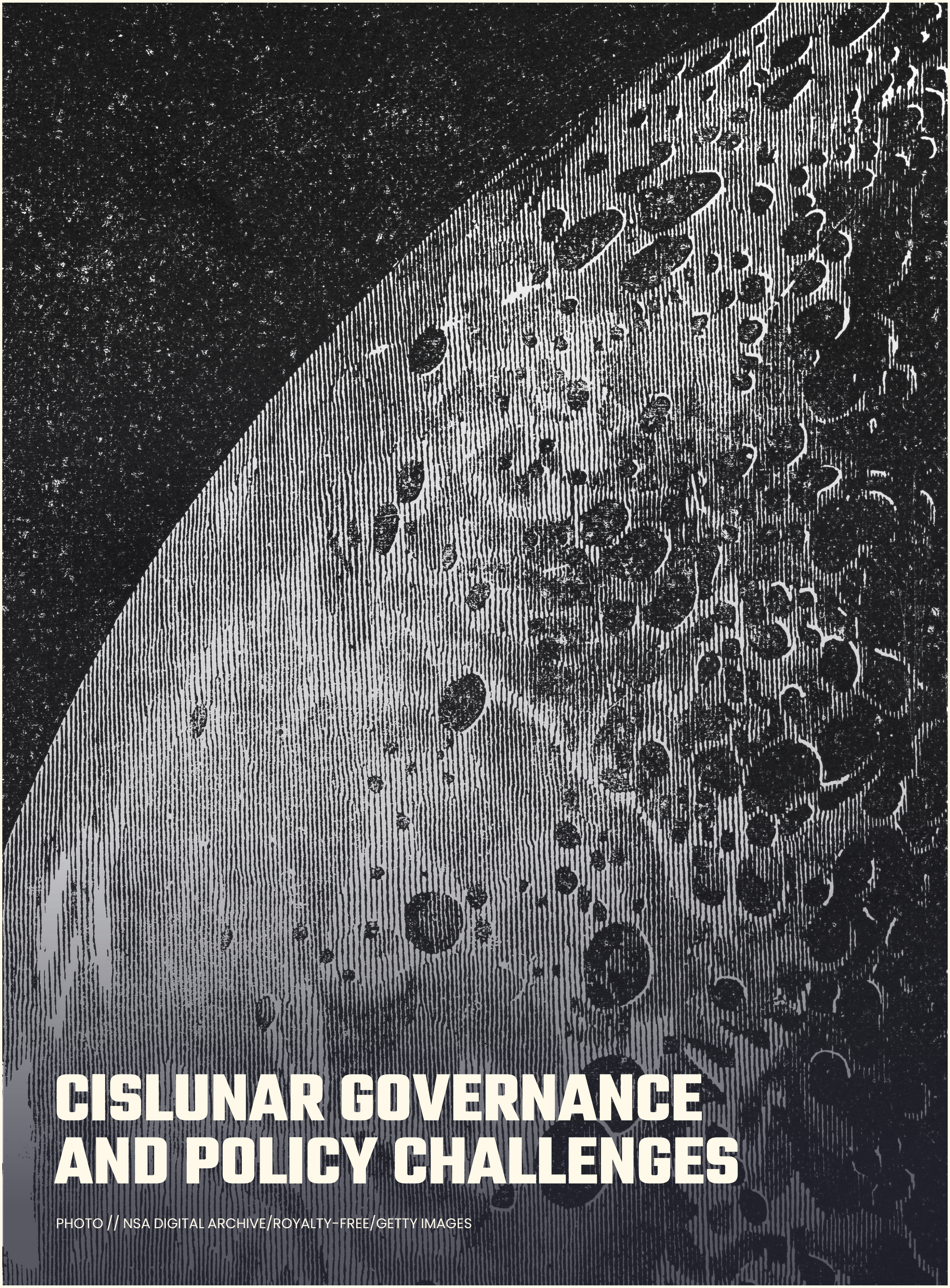
The council itself was not established by a formal international treaty but rather by the Ottawa Declaration, signed by representatives of the future council's membership. Its mandate covers a wide range of topics, including sustainable development of the Arctic region and environmental protection, but specifically excludes one topic: military security.[162]

There is no budget or secretariat for the Arctic Council. The council is only a forum and lacks the ability to implement or enforce any of the guidelines or recommendations approved during council meetings. However, council members negotiated and concluded the Arctic Search and Rescue Agreement in 2011, which addresses responsibilities and coordination for international search and rescue activities in the region.

THE CONVENTION ON INTERNATIONAL CIVIL AVIATION

The Convention on International Civil Aviation, signed in 1944, established rules for airspace, aircraft registration, safety and security, personnel licensing, aircraft communications, customs and duties, and environmental protections and addressed national jurisdictional questions related to air travel. It recognizes states' sovereignty over the airspace directly above their territory, which includes land areas and territorial waters. Parties to the convention must enact national laws that enforce convention rules and regulations and provide aircraft navigation services in their sovereign territories. Convention rules apply in the airspace above international waters, known as "high-seas airspace."[163]

The convention also set up the International Civil Aviation Organization (ICAO), the UN agency charged with coordinating standards and best practices for international air travel regarding topics such as air navigation, navigational infrastructure, flight procedures, cross-border aviation, and air-accident investigations. The ICAO is governed by a council—consisting of 36 members elected from the 193-member nations of the organization—that is responsible for adopting new standards and rules.[164]



CISLUNAR GOVERNANCE AND POLICY CHALLENGES

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There are policy, legal, and regulatory questions that impact current activities, as well as the future evolution of human activities, in cislunar space. These cislunar questions are generally the same ones that exist today for all other areas of space, whether in near-Earth orbits or beyond the Moon.[165] Governance questions applicable to cislunar space, therefore, should be addressed as much as possible so that resulting frameworks apply broadly to all regions of space.

> *These cislunar questions are generally the same ones that exist today for all other areas of space, whether in near-Earth orbits or beyond the Moon.*

To tackle cislunar governance questions, this report examines broader space governance matters, identifying key unresolved issues that resulted from either gaps in national and international frameworks or technological advancements that were not foreseen when space treaties were negotiated. Today, there are three main deficits in international space governance, which the report authors assert should be addressed to facilitate the safe, sustainable, and secure development of cislunar space. Governments should

- modify and elaborate upon rules regarding permissible activities in space,
- further define property rights in space and use of space resources, and
- establish rules of the road for human-made objects in space.

As the Moon is likely the first celestial body other than Earth on which humans might live and work, new space governance rules applying to cislunar space will not only involve spacecraft in space but also probably people and equipment interacting on the lunar surface.

The OST and three related space agreements—the Rescue and Liability Conventions and Rescue Agreement (not including the Moon Agreement due to its low number of signatories)—that established the foundations for international space law somewhat address these issues. However, there are no consensus definitions or meanings of certain key treaty phrases.[166]

Though there are few similarities between life on Earth and the harsh vacuum of space or surface of the Moon, elements of governance frameworks used to regulate areas on Earth beyond national borders, such as Antarctica and the high seas, should be assessed when considering how to update international space governance frameworks. The non-space governance frameworks described earlier in this report, some of which date to before the founding of the United Nations, have proven durable.

This section attempts to understand the reasons for that durability and discern lessons that can be applied to future space governance. For example, unlike the Antarctic Treaty System or UNCLOS, the OST did not establish a consultative mechanism or process for treaty parties to update space governance rules or address new issues that have arisen due to technological change, increasing commercial activities, and increased military interests in space.[167] The report authors discuss international space governance gaps and describe how non-space international agreements and frameworks have addressed similar concerns and considerations in their respective domains. Though the Moon Agreement is effectively not relevant to international space law, it is discussed as a reference that could help serve as a guide for a new agreement.

PERMISSIBLE ACTIVITIES IN SPACE

Broadly speaking, activities in cislunar space could include government activities of either a civilian or military character and commercial, private sector activities. The OST and Moon Agreement provide some, albeit broad, direction on permissible uses of space, including cislunar space. The OST calls for the exploration and use of space for the benefit of all nations but does not provide a comprehensive list of permissible activities. However, it does enumerate various non-permissible space activities, such as national appropriation of space and the placement of nuclear weapons or other weapons of mass destruction in space. Without referencing outer space writ large, the OST says that the Moon and other celestial bodies should only be used for peaceful purposes.[168]

The OST and Moon Agreement language relating to permissible activities drew upon the Antarctic Treaty, which placed similar, but not identical, constraints on what nations could do in Antarctica.[169] Like outer space, Antarctica was reserved for peaceful purposes, with an emphasis on scientific exploration and research. Any activities of a military nature are prohibited. Similarly, the OST prohibits military activities on the Moon and other celestial bodies, but not in outer space.[170]

Since signing the Antarctic Treaty, signatories have refrained from militarizing the continent, though experts disagree on what constitutes militarization. In contrast, there are military interests in space today. However, it is not clear what military advantages could be obtained specifically in or from *cislunar* space. Advocates for extending military operations into cislunar space acknowledge that the Moon's distance precludes it from having any direct and meaningful impact on terrestrial operations but suggest actions from cislunar space could affect space systems nearer to Earth.[171] In particular, these arguments assert that cislunar space is a high ground that can be used for deploying weapons against satellites in lower orbits and conducting space observation and surveillance.[172]

> *However, it is not clear what military advantages could be obtained specifically in or from* cislunar *space.*

For example, one report expressed concerns that China might use the Moon's gravity to slingshot hostile spacecraft around the Moon and into position to attack satellites in GEO or other orbits.[173] While technically possible, such technology—if developed and deployed—offers no strategic advantage over the myriad of counterspace weapons that could be launched today. It would also be a much more time-consuming way to deliver a weapon targeting a satellite in GEO than other possible methods. Slingshotting around the Moon to reach GEO takes a lot of time and is designed to save spacecraft fuel—not the kind of maneuvering that would underpin a successful military attack.[174]

One could argue that launching a counterspace weapon from cislunar space toward a satellite in GEO or lower orbits could offer a way to stage a surprise attack from an unexpected direction. While true, this advantage dissipates once it becomes known that such weapons are being deployed and possibly used. Improved cislunar SSA could certainly help provide advance warning of such activities, but since the vast majority of expected future cislunar missions are civilian, these SSA improvements should be the responsibility of civilian and commercial operators. However, military users could acquire cislunar SSA data from these sources, like they acquire other commercial space services like satellite communications.

Another reason given by proponents of conducting military activities in cislunar space is that it affords an ideal vantage to conduct space observation and surveillance and to assess counterspace operations at lower orbits. In reality, a system placed on the Moon or in halo orbits associated with the Earth–Moon L_1 and L_2 points could not provide continuous, persistent surveillance of any point on Earth or in lower Earth orbits. Earth itself would block cislunar observation platforms from having a persistent view of activities in near-Earth orbits.

Additionally, the Moon rotates around Earth about every 28 days, so it is not a static observation point relative to Earth. A system in cislunar space would lose track of areas for long periods of time. Plus, a spacecraft near the Moon is 10 times further from Earth (nearly 400,000 kilometers) than a spacecraft in GEO (about 36,000 kilometers). A network of sensors located on Earth, however, can provide persistent monitoring of activities in GEO, as is done today.

Scientists in China have proposed another cislunar use for space monitoring, publishing a paper on using a lunar gravity assist for placement into retrograde GEO, along the same plane on the same plane as Earth's equator.[175] Such an orbit, which would run in the opposite direction of standard drift, would allow a spacecraft to get a view of the entire GEO belt every 12 hours but pose significant collision risks to other satellites in GEO, with one expert noting it would be akin to driving a car the wrong way on a highway.[176] Additionally, a retrograde GEO system would not be able to examine any one spacecraft in detail due to the high relative velocities between such a monitoring system and other satellites in GEO drift orbits. There is also no clear benefit to using such a monitoring satellite rather than existing SSA sensors placed on Earth.

The larger question is: Under what circumstances should utilizing cislunar space for observation or collecting SSA data be characterized as a military use? Certainly, a military-owned and -operated satellite presumes a military use. But, as noted earlier in this section, improvements to cislunar SSA systems should be the focus of civilian and commercial operators. Civil-government or commercial cislunar capabilities that observe and characterize space activities, including a retrograde GEO system, could collect the same information and data as military-operated systems but would not carry the same militarization concerns. However, there is no reason military users should not have access to SSA data available from civilian and commercial sources.

Ultimately, the raison d'être for extending military forces into cislunar space seems tied more to national honor and fear that China might do something there first than to a real strategic military goal. If this is true, the situation looks no different than Antarctica in the 1950s. To save time and military resources that could best be used elsewhere, the two superpowers of that day wisely made the decision to keep military interests and the Cold War out of Antarctica.

In addition to questions about military uses of cislunar space, this report examines commercial, private sector uses. Like the Antarctic Treaty, the OST is silent on commercial, for-profit activities in cislunar or any part of space. But the OST does create room for broadly nongovernmental space activities by including a clause requiring nations to authorize and continuously supervise all national space activities by governmental and nongovernmental entities. This language satisfied both the Soviet Union, which sought to limit space to government-only missions, and the United States, which sought to permit commercial space developments.[177]

In the late 1950s and early 1960s, there was arguably little commercial appetite for space beyond nascent plans for commercial communications satellites—and certainly no business plans built around the extraction of space resources from the Moon, asteroids, or other space objects.

Space activity is now dominated by the private sector, though a significant percentage of commercial space activities are financed by governments. However, few of these current private sector space activities are related to the extraction or use of space resources.

Once it is possible to realize economic gains from resource extraction (or some other activity) on the Moon or other celestial bodies, nations will want a way to claim and protect their shares, as well as their national entities involved in those activities. The International Seabed Authority (ISA) established by the UNCLOS is an attempt to internationally regulate seabed mining, partly to avoid a rush to grab seafloor territory and bypass any motivations for a country to use armed force to assert national rights to ocean resources. The question, discussed in the next section, is whether a similar arrangement could work for space.

PROPERTY RIGHTS IN SPACE AND USE OF SPACE RESOURCES

Property rights stipulate how a resource can be owned and used and have existed in some form since ancient times. Today, property rights are closely tied to national sovereignty, determined by national law, and provided by the nation-state to entities under its jurisdiction. The one notable instance in which property rights originate from an authority other than the nation-state is the bottom of the ocean, which is defined by UNCLOS as the "common heritage of mankind."[178] In this case, property rights to the seabed and ocean floor, including to resources within those areas, are shared by all nations and people. According to this principle, no nation or entity can unilaterally claim or distribute those resources. Only the ISA, as established by UNCLOS, has that right.[179]

The use of resources in any domain is closely tied to property rights, namely that the decision to use a resource is predicated on the ability of that entity to first assert ownership of it. In space, property rights and national sovereignty are somewhat constrained by the OST. Specifically, Article II of the OST states that space, "including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means."[180] As already noted, legal scholars disagree on the meaning of "national appropriation," with some arguing it prohibits any property claims while others assert it allows for private appropriations of space resources.[181]

The OST does not provide clear direction on how national laws and regulations apply to space, but it does tacitly permit nations to exercise a degree of sovereignty in authorizing and continuously supervising their national space activities. Since the OST did not establish consultative bodies that regularly meet to discuss treaty implementation issues, like UNCLOS did with the ISA and the Antarctic Treaty System with its consultative meetings, there has not been an easy way to clarify this ambiguity.

Experts generally agree that the OST prohibits national claims to territory in space, including territory on a celestial body, such as the Moon or an asteroid.[182] But nations may still want to use these locations for their own national purposes. And the issue is that although outer space is large, there are certain locations, trajectories, or orbits that will have more value than others. There are probably only so many space objects that can safely occupy a given location, trajectory, or orbit at the same time. For orbits, this is sometimes called "orbital carrying capacity."[183] The Artemis Accords somewhat address this issue by creating safety zones, though the original intention of safety zones was to prevent harmful interference from one nation's space activity on another nation's space mission.

In cislunar space, many users will probably want to operate around the Earth–Moon Lagrange points, particularly L_1 and L_2. Though only points in empty space, the Lagrange points are special due to the gravitational balance between the Moon and Earth at these locations. Spacecraft can orbit these points using a Lissajous orbit or halo orbit. Halo orbits associated with the L_2 point are particularly useful because they provide a spacecraft a continuous line of sight to Earth and the far side of the Moon. Orbits associated with the L_1 point are useful because they provide a spacecraft a continuous line of sight to both Earth and the near side of the Moon.

In addition to orbits associated with Earth–Moon Lagrange points, space in low lunar orbit (LLO) around the Moon will also be valuable. Only certain inclinations in LLO are stable. Finally, the "peaks of eternal light"—the locations near the lunar poles exposed to the most sunlight each day—will also be valuable because they will be the best locations to build solar power infrastructure.[184]

Due to this legal uncertainty, there is currently no framework for adjudicating competing national claims to valuable locations in cislunar space, such as halo orbits associated with the Earth–Moon L_2 Lagrange point or high-value crater-ridge real estate (i.e., peaks of eternal light) on the Moon. There is also no universally agreed-to framework among all spacefaring nations on the legality of exploiting lunar resources such as ice and minerals. To date, nations have extracted small amounts of material from the lunar surface for analysis, sometimes bringing those samples back to Earth. But the salient question is how to address space resource use at scale, potentially for commercial gain. There is no space equivalent to the ISA for internationally licensing and regulating resource extraction (though the Moon Agreement would have established such a mechanism). This ambiguity creates significant uncertainty for legal protections for space activities and may hinder private sector space investments.

Most nations, including the United States, did not support the approach taken by the Moon Agreement on space resources. The United States criticized UNCLOS and the Moon Agreement for designating a region as the "common heritage of all mankind" as counter to free market principles. This language was a main reason the United States decided not to ratify UNCLOS.[185] Opponents of the Moon Treaty also expressed concerns that one of the goals of the agreement's proposed regulatory regime would be equitable sharing of benefits from lunar resources, as they worried this approach could disadvantage private sector initiatives.[186] This precedent suggests that a workable international framework for distributing space resources should not mirror such an approach.

To address the ambiguity of the OST language, the United States asserts through the Artemis Accords that the extraction and utilization of space resources does not inherently constitute national appropriation and can be accomplished in compliance with the OST.[187] By signing the Artemis Accords, many other nations have supported this interpretation. But there is no international consensus on the term "space resource," which does not appear in the OST text. As noted earlier, COPUOS has established a special working group to discuss the legal uncertainties around the term.

As another reference, the Antarctic Treaty System currently bans commercial resource extraction from Antarctica, though there was a failed attempt in the 1980s to add a new agreement establishing a mineral extraction regime. But the Antarctic Treaty never claimed that Antarctica was the common heritage of humankind. Spectrum is another finite resource, albeit somewhat different from seabed minerals or Antarctic oil deposits. To optimize the use of spectrum, the ITU facilitates international coordination—but does not license spectrum, a role performed by national regulators.

Ultimately, though the United States has made clear it has no intention of claiming territory in space, whether on the Moon or anywhere else, its position on the use of space resources and concepts like safety zones could be disingenuously used by China and Russia to grab territory, claiming they were only following U.S. precedent. Opening this door has the potential to create a rush to claim resources, which effectively means claims on associated lunar real estate by designating safety zones. This is exactly what the OST aimed to prevent, as well as what the Antarctic Treaty, the UNCLOS through the ISA, and the ITU sought to avoid in their own domains.

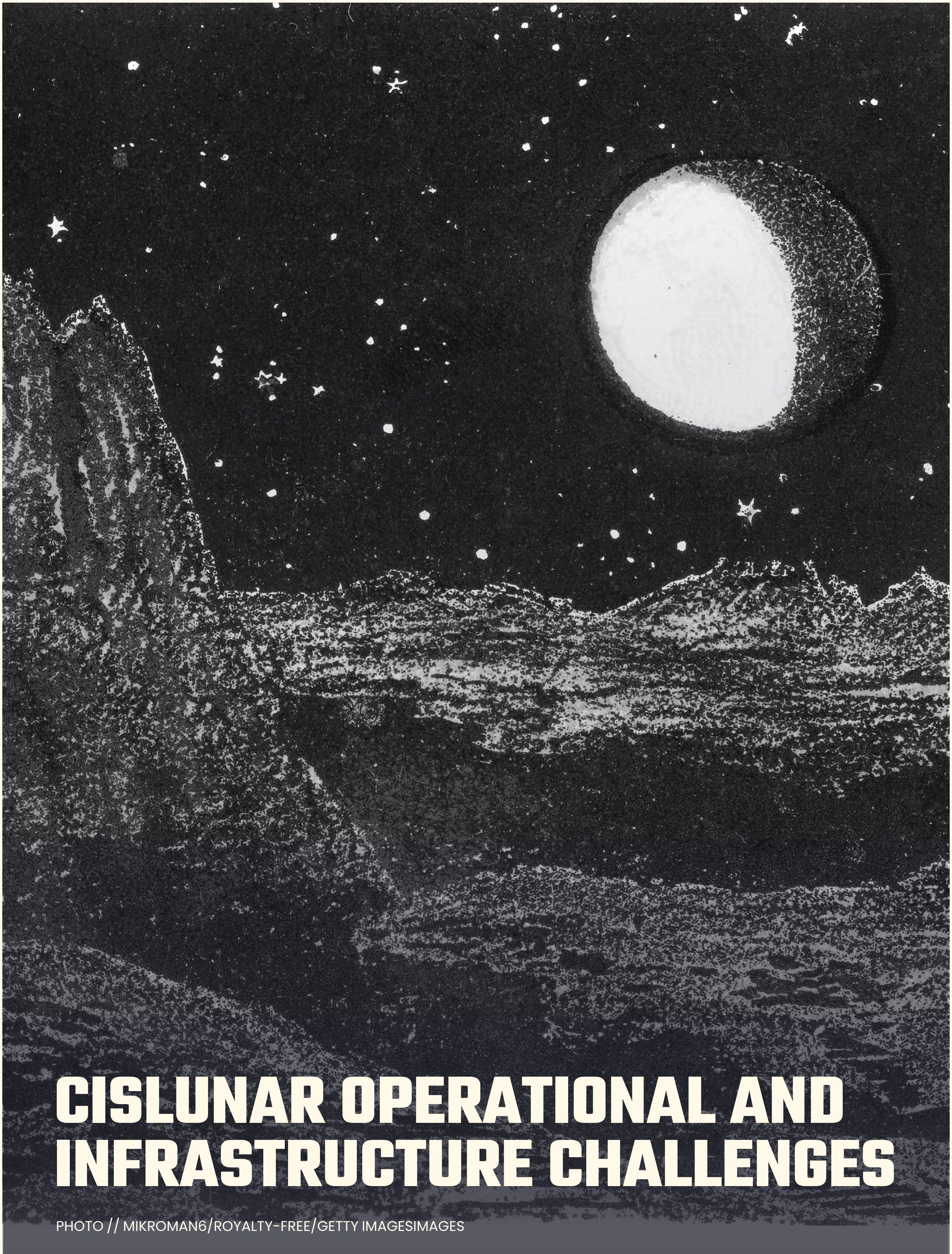
SPACE RULES OF THE ROAD

The main reason to develop rules of the road for space, including cislunar space, is to prevent collisions between space objects. In the sea domain, this was the same goal that drove the development and introduction of the COLREGs designed to prevent collisions of ships. There is no internationally agreed-to set of rules or regulations on spacecraft behaviors or collision avoidance, though some nongovernmental organizations—such as the Space Safety Coalition, which has international participation—have put forward guidelines for space behaviors.[188]

The only reference to space behaviors is contained in Article IX of the OST. This section stipulates that treaty parties must conduct their space activities "with due regard to the corresponding interests of all other States Parties to the treaty" and should consult with each other in cases where one nation's activities could "cause potentially harmful interference" to another's.[189] As with other terms used in the OST, there is no definition of "due regard" or "harmful interference" in the text and no treaty-specific mechanism or venue to provide the needed clarifications.

Outside the United Nations, the United States has tried to make progress on space safety through the Artemis Accords. Helpfully, the Artemis Accords establish a "safety zone" concept—originally envisioned by the Hague Space Resources Working Group Building Blocks—intended to prevent harmful interference between national space activities.[190] However, the Artemis Accords do not create new obligations for parties to the OST, which already requires signatories to coordinate when they expect "harmful interference"—a term that remains undefined in either treaty.

The long-term sustainability guidelines developed by COPUOS could help shape future efforts to develop COLREG-like rules for space, but the guidelines themselves lack the required specificity to serve as rules of the road for space operations. The ATLAC recently established by COPUOS also could develop the foundation for future rules of the road for lunar space activities.



CISLUNAR OPERATIONAL AND INFRASTRUCTURE CHALLENGES

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There are several cislunar operational and infrastructure challenges that, if unaddressed, will cause increasingly significant impediments to the safety, sustainability, and efficiency of cislunar operations. Though some of these challenges result from a lack of physical infrastructure and equipment needed to support a sustained crewed and uncrewed lunar presence, others stem from gaps in coordination mechanisms and agreed-to processes for operating in cislunar space. This section outlines several of these challenges, attempting to describe specifically whether the problem stems primarily from inadequate infrastructure or a lack of operator coordination processes.

SPACE SITUATIONAL AWARENESS

Fundamentally, SSA is knowledge of the current and predicted future locations of objects in space.[191] Objects in space can be detected and tracked using a variety of sensors, such as radar, optical, laser-ranging, and radio-frequency (RF) technologies. Terrestrial radar systems are typically used for detecting and tracking objects in LEO, including operational and non-operational spacecraft and debris fragments. For GEO, terrestrial optical telescopes are usually used for detecting and tracking objects, as radar signals are usually not powerful enough to track objects at such distances. Satellites equipped with optical sensors and cameras can also provide SSA data. Since virtually all operational spacecraft emit RF signals, RF receivers on Earth or other spacecraft can be used to detect and track active spacecraft in all orbits.[192]

In addition to data derived from these sensor systems, many satellites are equipped with GPS receivers, allowing operators to know the precise location of their satellites at any time. Some operators choose to share location information for their satellites with other operators, government entities, or third parties such as the Space Data Association, an international nongovernmenal organization that facilitates operator-to-operator information sharing.[193]

All these SSA technologies were designed to track objects in lower Earth orbits, though most could be used for tracking objects in cislunar space. For example, terrestrial optical telescopes and RF sensors could track operational spacecraft. Spacecraft with optical sensors and cameras in cislunar space could likely also be used for cislunar SSA purposes. However, just as it is not feasible to use radar for tracking objects in GEO, power requirements make it difficult to use terrestrial radar systems to track cislunar objects. Laser-ranging systems might be feasible for tracking objects in cislunar space.

An object in GEO can be tracked by an optical telescope or RF receiver at a fixed location on Earth's surface. Objects in LEO are tracked by ground-based radars that do not maintain positive custody of each tracked object as it orbits Earth. Rather, an object's position is confirmed when it passes over a radar site. At all other times, its position is predicted based on Keplerian orbital dynamics.

Irrespective of the sensor phenomenology, detecting and tracking objects in cislunar space requires, at a minimum, a network of terrestrial sensors located around the globe. Unlike objects in GEO, whose orbital period is the same as Earth's rotation, objects in cislunar space, as well as in LEO and medium Earth orbit (MEO), orbit Earth at a rate different from the speed at which Earth revolves on its axis.

Objects in LEO and MEO orbit Earth at a speed faster than the rotation of Earth on its axis, while objects in cislunar orbit at a slower rate than Earth's rotation.[194] Terrestrial sensors tracking objects in cislunar space need to hand off and receive custody of tracked objects as cislunar space rotates from and into the sensors' fields of view. Detecting and tracking objects in cislunar space will require a new approach that differs from the ones used for LEO, MEO, and GEO objects. Additionally, the power requirements for ground-based radar to reach cislunar space would likely rule out its use for detecting and tracking cislunar objects.[195]

Finally, any Earth-based sensor would lose custody of objects in lunar orbit as they transit around the side of the Moon that is always facing away from Earth. Given that the rotational period of an object in stable lunar orbit is as little as two hours, it would be possible to quickly reacquire the position of space objects once they reappear on the Earth-facing side.[196] Keplerian orbital dynamics would apply to stable lunar orbits, so it would be possible to predict the position of objects during transit around the Moon's far side.

SPACE OBJECT TRACKING AND TRAFFIC COORDINATION

The DoD began tracking and cataloging satellites with the launch of Sputnik in 1957. In the 1960s, it started developing mathematical equations and source code used to predict the positions of satellites in Earth orbit. By the 1970s, the DoD and NASA adopted a standardized model and the two-line element (TLE) set format for space object tracking and position predictions.[197] After the public release of the models, the TLE format became the industry standard for predicting satellite position.[198]

Today, TLE datasets are used for various purposes. In conjunction with operator-to-operator information and maneuver plan sharing, government and private sector satellite operators use TLE data for planning and managing daily satellite operations. Militaries use TLE data to track the satellites and spacecraft of other nations as part of SSA operations. Astronomers and amateur space object trackers on Earth use TLE datasets to plan space observations. Launch operators and government and commercial operators planning on-orbit activities also use TLE data for planning purposes.

Keplerian orbital mechanics, used to model objects in GEO or lower orbits, assume any two objects with mass—for example, Earth and a spacecraft—will impact each other's orbital position. This is called a "two-body problem." Unlike objects in these lower orbits, objects in cislunar space are also affected by the mass and gravity of the Moon. This is called a "three-body problem." This means that cislunar trajectories cannot be effectively approximated or predicted using equations designed for Keplerian orbital mechanics.[199] Object predictions from models used today for objects in GEO or lower orbits would remain accurate for only a very short period because the TLE format and its underlying equations are not suitable for non-Keplerian, three-body-problem conditions.

Since 2011, NASA has relied on the Multimission Automated Deepspace Conjunction Assessment Process (MADCAP), managed by the Jet Propulsion Laboratory, to assess the risks of collision for spacecraft orbiting the Moon and Mars. Given the lack of SSA infrastructure beyond GEO, the positions of spacecraft orbiting the Moon and Mars are provided by operators using radiometric tracking involving ground-based antennas.[200] Some scientists are also trying to use very long baseline interferometry (VLBI) to track objects in cislunar space.[201] Both of these techniques require that the object being tracked emit a radio signal, so this method could not be used to track non-operational satellites or inert space debris or fragments.

POSITIONING, NAVIGATION, AND TIMING

Currently, global PNT data from satellites is provided by four different navigation satellite systems: the United States' GPS, Russia's Global Navigation Satellite System (GLONASS), China's BeiDou Navigation Satellite System, and the European Union's Galileo. The systems are all located in MEO at altitudes between 19,000 kilometers and 24,000 kilometers.[202] There are also two regional PNT systems: the Indian Regional Navigation Satellite System (NavIC) and Japan's Quasi-Zenith Satellite System (QZSS).

Since these satellite networks are designed to provide PNT data to terrestrial users, their signals are directed toward Earth and not deep space. Unless PNT signals are received on Earth and redirected into cislunar space or PNT satellite systems are redesigned to transmit into space as well as toward Earth, spacecraft in cislunar space would need some other way to reliably determine their position and establish timing. As described in earlier chapters, the United States, China, and Europe have plans to create lunar PNT infrastructure.

It is worth recalling that the Apollo missions were able to use two different navigation methods on their journeys to the Moon and back. Their main source of navigation data came from radio signals exchanged between the Apollo spacecraft and ground stations on Earth. The position of the Apollo Command Module could be calculated by measuring the Doppler shift of signals from the spacecraft, transmitting and analyzing ranging signals sent to the spacecraft, and using two receivers on Earth to conduct VLBI analysis on Apollo signals. Additionally, the Apollo spacecraft were equipped with inertial guidance systems, which do not require external signals to operate.[203] For Artemis missions, NASA's Orion capsule uses an inertial guidance system, GPS receivers, star-tracking technology, and an optical camera-based navigation system. Like Apollo, Orion—or any cislunar spacecraft emitting radio signals—can be tracked from Earth using VLBI techniques.[204]

In addition to the provision of real-time data on position, a spatial reference and associated coordinate system is needed for both cislunar space and the surface of the Moon to precisely measure locations within the given reference framework. A three-dimensional reference system would be needed for cislunar space, while a two-dimensional system would suffice for the lunar surface.[205]

Commonly used for objects in Earth orbit, an Earth-fixed coordinate system using x, y, and z measurements from Earth's center could be used for objects in cislunar space. Alternatively, a Moon-fixed coordinate system could be created using x, y, and z measurements from the center of the Moon. Either a spherical coordinate system using latitude and longitude or a standardized Cartesian coordinate system that models the Moon as a flat plane would work for the Moon's surface. An example of a Cartesian coordinate system used for Earth is the Universal Transverse Mercator. Currently, the National Geospatial-Intelligence Agency, NASA, the U.S. Geological Survey, and the U.S. Space Force are collaborating on an effort to design a reference system for the Moon.[206]

In addition to the difficulties receiving timing data from GPS or other existing PNT systems in cislunar space, time itself behaves differently on the Moon due to the theory of relativity. The motion of the Moon relative to Earth, as well as its lower gravity, means that time actually moves 56 microseconds faster on the Moon than on Earth each day. While this difference may seem unimportant on the surface, precision time measured to nanoseconds is typically needed for navigation. Even if the moon had its own PNT constellation, potentially like what ESA envisioned as part of its Moonlight initiative, there would still be a 56-microsecond discrepancy per day between lunar time and Earth time.[207] In April 2024, as part of the National Cislunar Science and Technology Strategy, the White House directed NASA to lead and coordinate with other federal agencies on efforts to establish a lunar time standard.[208]

DEBRIS AND DETRITUS

Only 12 humans have been to the Moon, but humankind has already left a significant amount of trash on the lunar surface. The current tally includes boosters from over 50 crashed landings, almost 100 bags of human waste, and miscellaneous items such as golf balls, boots, and a feather. In total, it is about 200 tons of trash.[209]

To date, according to experts, there are only a few dozen pieces of human-made space debris in cislunar space.[210] But it may prove difficult to keep debris levels low, as there are no internationally agreed-to, end-of-life disposal guidelines for spacecraft operating in cislunar space and no standard debris-mitigation procedures. Additionally cislunar operators are already facing increased collision risks between the few spacecraft in lunar orbit, heightening the risk that collisions produce debris fragments.[211] A lack of agreed-to, cislunar, operator-to-operator, space-safety, coordination, and data-sharing mechanisms—particularly ones that include China—probably leads to increasing collision risk and debris-fragment creation.

Any debris fragments near the Earth–Moon L_4 and L_5 Lagrange points might produce particularly acute risks to cislunar operators in these areas. At these stable equilibria, balanced gravitational forces trap both natural and artificial debris into clouds, posing physical risks to satellites stationed at or around these points. This same problem does not exist at L_1, L_2, or L_3, all of which are unstable equilibria and thus allow debris to dissipate more easily.[212]

RADIATION

Objects in cislunar space are exposed to higher levels of solar radiation (also called "solar energetic particles") and cosmic radiation (also called "galactic cosmic rays") than those experienced nearer to Earth, posing a risk to microelectronics and human safety. Unprotected by either an appreciable atmosphere or magnetic field, the lunar surface is battered by intense solar radiation when facing the Sun.

Due to the orbit of the Lunar Gateway around the Moon, it will be positioned in interplanetary space 80 percent of the time.[213] This is a very different environment than near-Earth orbit—the location of every other long-term habitable space station to date, where the main source of radiation is the inner Van Allen belt, produced when cosmic radiation interacts with Earth's magnetic field. When compared to past stations, the Lunar Gateway will experience notably higher levels and greater intensities of cosmic radiation, which has a higher relative biological effectiveness (i.e., to what extent a dose of radiation affects human tissue) than Van Allen–belt radiation.[214]

Microelectronics can unexpectedly fail if they are not appropriately designed to withstand the expected levels of radiation in cislunar space. In July 2024, NASA revealed that microelectronics in the Europa Clipper spacecraft probably do not have sufficient radiation hardening to survive the radiation environment around Jupiter; however, NASA later cleared the spacecraft for launch, determining it could withstand the expected radiation.[215] Meanwhile, Firefly's first CLPS mission, slated for launch in 2024, will carry the RadPC-Lunar payload, a radiation-tolerant computing system built under the LSITP program, to test the architecture's ability to operate in high-radiation environments.[216]

Existing technologies can be used to shield equipment and spacecraft from radiation levels expected on and near the Moon; however, since shielding adds costs and weight, engineers designing lunar systems will need to carefully balance requirements for radiation protection with other considerations impacting overall system requirements.

LUNAR REGOLITH

The solid rock of the Moon's surface is covered in regolith, a layer of loose, dust-like material composed of small, electrostatically charged particles made by meteor impacts. The average particle size of this lunar dust is about 72 micrometers. For comparison, the width of a human hair is on average about 100 micrometers and the size of a particle of grass pollen is about 25 micrometers.[217] Medium-grain sand is about 500 micrometers in size.

As there is virtually no air on the moon, wind does not disturb the regolith. Rather, the regolith can be disturbed by electrical force (since it is composed of charged particles), micrometeoroid impacts, and engine landing and launch plumes. Due to the low gravity of the Moon and lack of air to slow down the particles by drag, engine plumes can eject regolith at very high speeds (measured in several kilometers per second) over very large distances.[218] Additionally, these plume–surface interactions are presently poorly understood, making the effects that lunar landings may have on surrounding spacecraft unpredictable. A payload built by NASA flying aboard Firefly's first CLPS mission, known as Stereo Cameras for Lunar Plume Surface Studies (SCALPSS) 1.1, will image the behavior of the regolith as the lander touches down on the Moon to better understand the surface effects of lunar landings.[219] The collection of in situ data will complement NASA's existing efforts to model and predict these interactions.[220]

Previous operations on the Moon have demonstrated that regolith can harm electrical and mechanical systems. Lunar regolith and dust also pose a risk to humans, causing issues with respiration. Since the early days of the space race, operators of missions to the Moon have had to contend with the impacts of lunar regolith on their missions. In fact, as Apollo 17 commander Gene Cernan observed, "Dust is probably one of our greatest inhibitors to a nominal operation on the Moon."[221] Lunar activities that disturb and generate plumes of regolith have the potential to cause problems, especially in areas such as the lunar south pole, where there is expected to be a relatively high density of missions from a variety of nations.

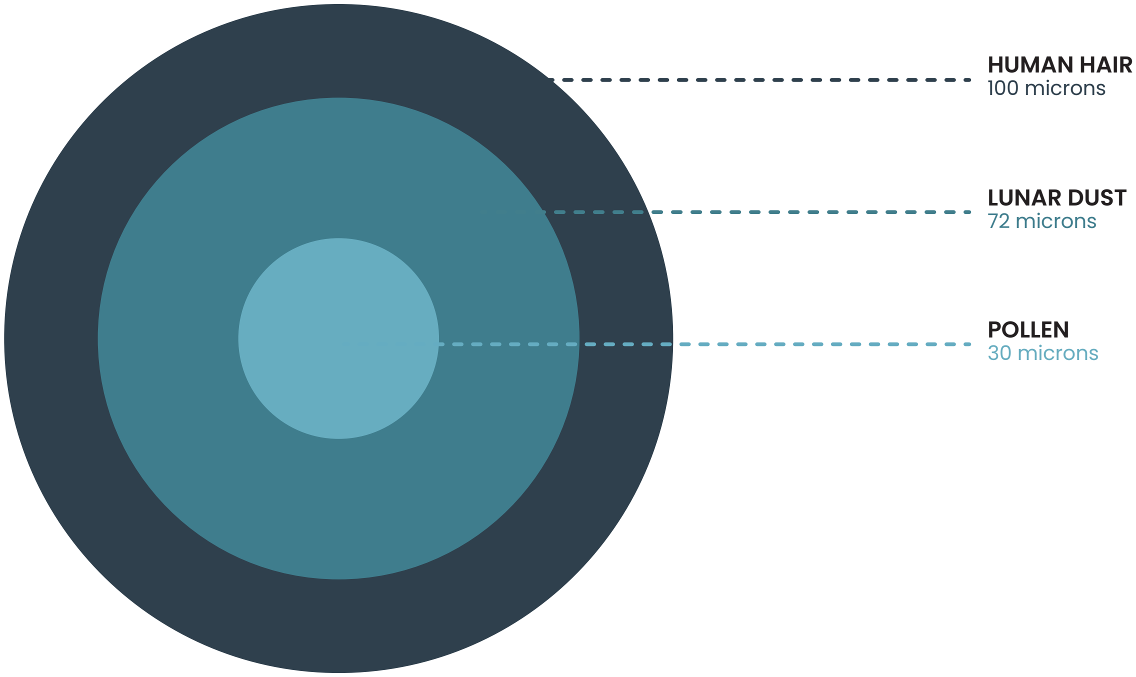


Figure 7: Regolith Size

Source: Kristen John, "The Challenge of Lunar Dust," NASA, June 8, 2022, https://ntrs.nasa.gov/api/citations/20220008062/downloads/The%20Challenge%20of%20Lunar%20Dust%20-%20v4.pdf.

To address concerns about lunar dust, many experts cite the need for greater coordination between lunar operators to prevent harmful interference between space systems, particularly around spacecraft launch and landing sites. The concept of a safety zone enshrined in the Artemis Accords is one such effort to establish a coordination approach to mitigate impacts of lunar dust on lunar operations.

In addition to policy solutions, experts have raised technical solutions to the hazards posed by dust. To this end, NASA has developed an electrodynamic dust shield, which prevents dust accumulation using electric fields, and plans to send this payload to the Moon in 2024 aboard the Blue Ghost M1 mission.[222] NASA is also exploring the use of different materials to prevent dust accumulation on sensitive surfaces such as solar panels, sensors, and optical systems. To test the "stickiness" of lunar regolith to different objects, NASA is launching its Regolith Adherence Characterization payload aboard Blue Ghost M1 to measure regolith accumulation rates across different test materials.[223]

HEAT AND POWER

Temperatures on the lunar surface range from 250 degrees Fahrenheit (121°C) during the lunar daytime to -208 degrees Fahrenheit (-133°C) at night. There are some places on the Moon where temperatures can drop to -410 degrees Fahrenheit (-246°C) or lower.[224] Microelectronics cannot typically survive these extreme temperature swings, which can make materials brittle and damage connections.[225] To survive the intense cold and heat, electronic equipment on the lunar surface needs to have power to regulate temperature.

The lunar night itself also creates power-generation and power-storage challenges that will need to be addressed for sustained operations. For example, spacecraft orbiting the Moon and on the lunar surface using solar power must have sufficient battery capacity (or another form of power storage) to operate throughout the lunar night.

There are several locations on the Moon that, while not always receiving light, are exposed to longer periods of sunlight than most locations on the lunar surface. Referenced earlier in the report, these are called peaks of eternal light, a term whose original meaning referred to theoretical points on any celestial body that are always lit by the Sun.[226] On the Moon, these points are located on the ridges of craters in both the north and south poles.

Placement of solar power generation equipment at these locations would have the advantage of being able to produce electricity more consistently. These locations will undoubtedly become valuable lunar real estate, and infrastructure built by one nation on these ridges could influence the value of nearby positions. Specifically, construction of equipment at one location may impact the ability of other nearby locations to see the Sun, possibly creating shadowing over what had previously been a peak of eternal light. Currently, there is no lunar power grid to transmit electricity from these locations near the poles to other parts of the Moon. Additionally, the accumulation of lunar dust and regolith on the surface of solar panels risks dampening electricity generation. This risk will be particularly pronounced in areas of potentially high landing activity, such as the lunar south pole, due to plume–surface interactions.[227]

Looking beyond solar power, nuclear power systems offer attractive solutions for the Moon because they are not dependent on the Sun and can provide consistent generation throughout the lunar day and night. In 2022, NASA and the U.S. Department of Energy announced contracts with three companies to begin work designing concepts for nuclear power systems to be placed on the Moon.[228] Additionally, Roscosmos announced in May 2024 that it is considering building a nuclear power plant on the Moon in partnership with China.[229]

COMMUNICATIONS

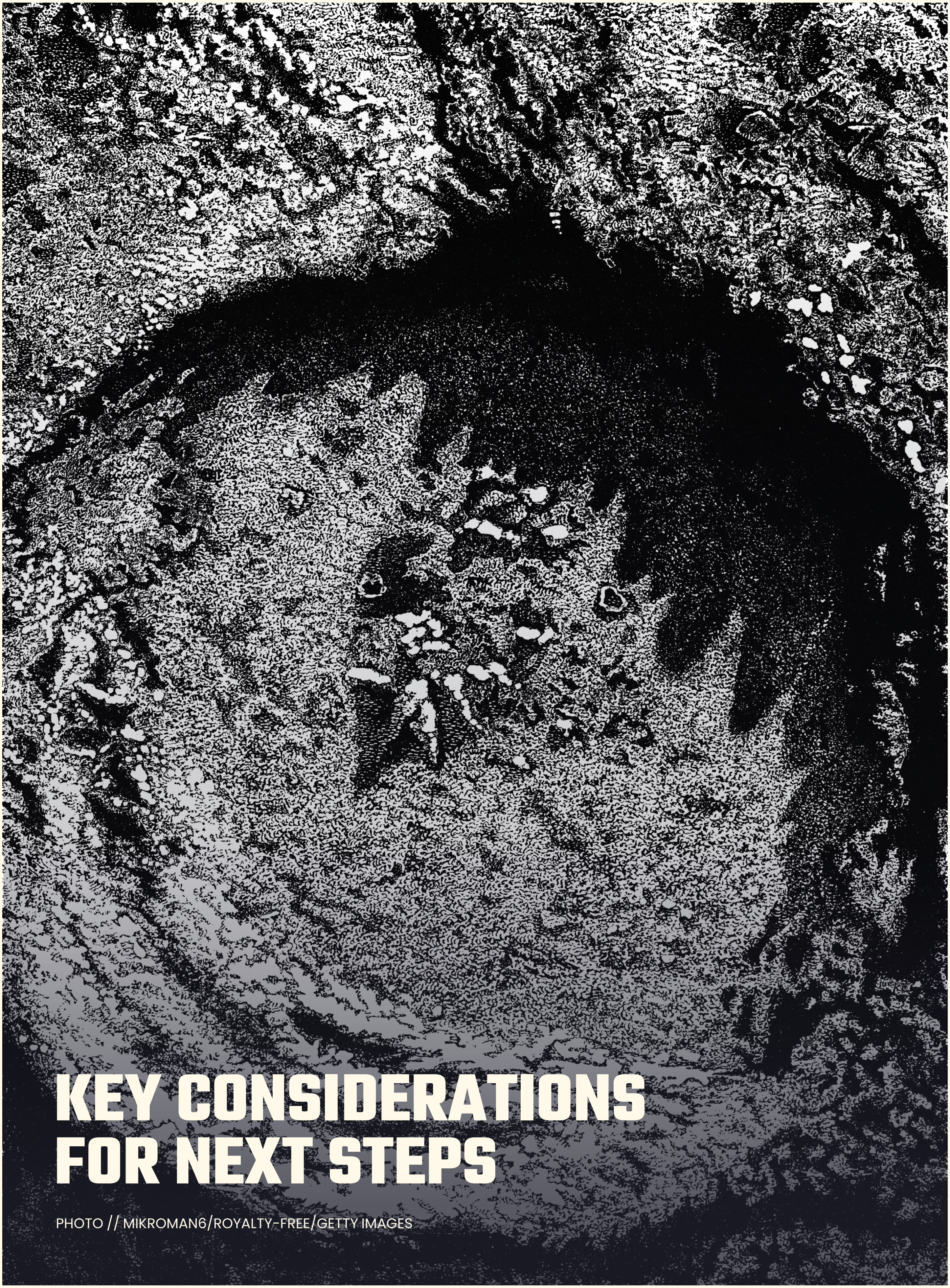
A spacecraft in orbit around Earth can only communicate when it has line of sight to ground stations, also called "gateways," that are configured to support communications for that particular spacecraft. Often, a spacecraft is not in continuous communications with Earth, as there are times during its orbit when there are no suitable ground stations within line of sight. In some cases, satellites in orbit share ground station infrastructure, so satellite operators have to preschedule transmission times on specific ground-based antennas.

However, satellites in GEO can maintain continuous communications with one ground station, rather than having to hand off communications between ground stations, because the orbits of those satellites mean they are always stationary relative to a point on Earth's surface. For this reason, NASA operates a constellation of satellites in GEO that can maintain communications with specific ground stations while serving as a data relay for spacecraft in lower Earth orbits.[230]

Due to the large distances, communications between Earth and spacecraft beyond GEO require larger ground-based antennas with higher gain than those used for communications with spacecraft in near-Earth orbits. This means that NASA equipment and other similar infrastructure designed for communications with spacecraft beyond GEO, such as NASA's Deep Space Network (DSN), is limited and usually in high demand. Communications are scheduled for short windows dependent not only on the availability of bandwidth, but also on when the ground infrastructure has line of sight to the spacecraft. Like the DSN, China operates a deep-space communications network that could support lunar communications.[231] The European Union also operates a deep-space communications system called European Space Tracking (ESTRACK).[232]

Any increase in cislunar activities will place additional strain on already taxed communications capacity able to support lunar missions. In addition, given that one side of the Moon always faces away from Earth, connectivity for all parts of the Moon will also require a way to relay data from the far side of the Moon. This will necessitate a relay satellite or infrastructure on the lunar surface to transmit data around the Moon. As noted earlier, China is currently operating two lunar relay satellites and has plans to build additional lunar communications infrastructure. Described in earlier sections, the U.S. LunaNet framework and the European Moonlight initiative are also focused on fielding new lunar communications capabilities.

Several private companies are currently attempting to establish private communications networks in hopes of supplying lunar communication capabilities as a service to lunar and cislunar operators. Intuitive Machines is planning on launching its Khon-series relay satellites aboard its CLPS missions.[233] These satellites will form the core of Intuitive Machines' Khonstellation, its cislunar data-relay service. In 2024, NASA awarded Intuitive Machines a contract for providing lunar communications and navigation services, in addition to awarding Intuitive Machines a study contract for a lunar communications and navigation user terminal and Aalyria Technologies a study contract on lunar networking.[234] Also slated to launch aboard an Intuitive Machines mission is a Nokia cellular network funded through NASA's Tipping Point initiative that will enable communication between the Nova-C lander, the Micro-Nova hopper, and Lunar Outpost's rover, establishing the first cellular network on the Moon in order to demonstrate the feasibility of such a network for future missions.[235] Additionally, ispace is planning on deploying two relay satellites during its APEX 1.0 mission, slated for 2026, as part of a future data-relay service.[236]



KEY CONSIDERATIONS FOR NEXT STEPS

PHOTO // MIKROMAN6/ROYALTY-FREE/GETTY IMAGES

Looking forward, it is worth restating the anticipated amount of U.S. and foreign cislunar activity expected in the decade ahead. In total, there are about 40 significant missions, though often several payloads are associated with each mission, from all nations headed to the Moon over the next several years, with many of those missions associated with NASA's Artemis program and CLPS initiative.[237]

There is no indication of a lunar gold rush because there are no strong revenue-generating businesses centered around cislunar activities anchored by commercial customers. The Moon's surge in commercial activity is tied mostly to NASA's CLPS program, where many payloads ferried to the lunar surface are for NASA and commercial rideshare payloads are effectively subsidized by NASA. Truly commercial uses of the Moon remain a chimera, with no obvious sign this could change in the next several years. The cislunar domain is dominated by government activities, with the missions planned for the next decade operated by governments, strongly tied to government funding and use, or taking advantage of government-subsidized rideshare missions.

There is no indication of a lunar gold rush because there are no strong revenue-generating businesses centered around cislunar activities anchored by commercial customers.

Though the United States has released a cislunar technology strategy, it has not articulated a comprehensive national cislunar strategy or goals, nor a cislunar national security strategy. However, the U.S. Space Priorities Framework provides sufficient guidance to help shape U.S. cislunar efforts. Given the lack of clear commercial business cases for cislunar space, with no indication this absence is due to government action or inaction, efforts aimed at addressing the cislunar challenges identified in this report should primarily focus on furthering U.S. government requirements and not premature—or potentially imaginary—commercial ones.

ADDRESSING CISLUNAR GOVERNANCE GAPS

This report asserts that international space governance frameworks lack needed clarity and definition in three main areas: space rules of the road, property rights and resource use, and permissible activities. These governance gaps are not unique to cislunar space. The same lack of clarity and definition for these areas in current space treaties equally applies to activities in other parts of space.

As international space activities increase, particularly by the United States and China, space will become less safe and secure if these deficits are not addressed. A lack of agreed-to and followed space rules of the road will increase spacecraft collision risks. A lack of consensus by spacefaring nations on property rights, space resources, and permissible activities will lead to a greater chance of misunderstandings and miscalculations by space powers, potentially increasing geopolitical tensions and sparking conflict on Earth. Ultimately, a lack of consensus increases many dimensions of risk: risk of misunderstandings, risk of collisions, risk to businesses and investment decisions, risk to life and property, and risk of conflict.

These hazards are particularly acute for cislunar space. Fortunately, there are various international efforts trying to fill these gaps, some by the United Nations and another, potentially complementary initiative in the United States' Artemis Accords. No matter the forum or agreement, the solution should involve both the United States and China. In 2023, the United States and China together accounted for around 80 percent of the world's space launches. Most of the planned missions to cislunar space over the next decade are sponsored or supported by these two countries.

Agreement between the United States and China on an approach to address the cislunar space governance gaps discussed in this report would de facto establish the international standard. But neither the United States nor China can unilaterally fill those gaps, as each nation will throw sand in the gears of any attempt by the other to impose its will on the world. This is no different than U.S. and Soviet behavior during the Cold War. Other entities such as Russia, India, and ESA are still important, but they are not kingmakers.

While there is no need to disregard or contradict the OST and other international space agreements, addressing the identified space governance gaps need not happen as part of UN processes. There are over 100 nations in COPUOS, only a small fraction of which operate spacecraft. An even smaller fraction has a space launch capability, and fewer still have cislunar plans. The COPUOS ATLAC could provide a forum for U.S. and Chinese dialogue on cislunar governance questions, though it is too early to predict its chances of success—especially as COPUOS members continue to disagree on whom to name as vice chairs of the body.

Looking for ways to address thorny international issues outside of UN processes is not a new idea. Consider the Antarctic Treaty, whose groundwork was laid not at the United Nations but by the IGY and a subsequent conference organized by the United States that included only 12 nations. Interestingly, the United States has endorsed a concept for an International Lunar Year, taking inspiration from the IGY and International Polar Year of 2007 to 2008, possibly opening the door for an approach to cislunar space modeled after Antarctica.[238] Additionally, the Arctic Council was formed using a similar mindset; only nations with Arctic territory have a vote. These models could be applied to new cislunar space governance negotiations. This might mean setting criteria for participation in a new international convention on space issues that relates to a nation's stake and existing presence in space. Only nations that meet the criteria get a seat at the table.

At a minimum, the United States and China need a seat, particularly on measures and frameworks designed to ensure the safe and sustainable use of the space environment. Approaches that produce multiple governance frameworks overlapping with the same operational environments and geographical regions of space increase risks for space operators. International air travel and maritime shipping only work as well as they do because national leaders negotiated and agreed to one set of rules governing global air travel and one for maritime traffic.

It would not be a good outcome to have more than one set of rules of the road for space—for example, one agreed upon by the United States and its traditional allies and one agreed upon by China and perhaps Russia. That would be like having cars on the same highway following different sets of traffic rules. There is no reason to think China could unilaterally impose its own rules on the United States or that the United States could impose its own rules on China. This is arguably the limit of the Artemis Accords, as China is unlikely to sign onto it. But the principles outlined in the accords could be used during any future discussions and negotiations with China on new cislunar space governance rules.

LEARNING FROM EXISTING GOVERNANCE FRAMEWORKS

To frame and inform initiatives aimed at filling cislunar space governance gaps, this report introduced and discussed existing treaties and arrangements covering non-space domains that could offer lessons for space. Since no existing non-space framework has every element needed to cover all space governance gaps, the report's authors have described which parts of each system could apply to space and cislunar activities.

One lesson from the non-space examples is that national leaders did not let unbridgeable differences on issues tangential to core topics undermine efforts to negotiate consensus positions. For example, the Antarctic Treaty avoids any position on territorial claims, as the treaty drafters realized that no consensus on that issue was possible. Insistence on addressing claims would have torpedoed the agreement. In a similar vein, the Arctic Council excludes military matters from its agenda, recognizing that all nations with Arctic territory already use the region for military purposes and have no desire to coordinate on that topic with potential adversaries. The council's founders instead focused on areas where member interests overlapped, such as sustainable development and environmental protection of the region.

Another lesson from the non-space frameworks is that there is no one-size-fits-all approach for structuring negotiations or the final form of an agreement. Except for the Arctic Council, all of the non-space frameworks discussed originate from official treaties. Though it is merely an intergovernmental forum, deliberations in the Arctic Council have produced three official treaties and been effective at maintaining dialogue and coordination between Arctic nations. Of the non-space frameworks, only UNCLOS originated directly from a UN-facilitated process. For example, the negotiations that produced the Convention on International Civil Aviation pre-dated the creation of the United Nations. The Antarctic Treaty was negotiated specifically outside of the United Nations so that the agreement would not be influenced by the UN General Assembly and members with no contemporary presence on the continent.

> *Another lesson from the non-space frameworks is that there is no one-size-fits-all approach for structuring negotiations or the final form of an agreement.*

A final lesson—perhaps the most important of the three—is that the non-space frameworks described in this report are durable because they can evolve over time. Each of the frameworks has consultative mechanisms baked into its structure so there is no need to negotiate a new treaty or agreement and involve the entire UN General Assembly or the 102-member COPUOS to make decisions. These mechanisms have allowed framework parties to update and clarify aspects of their governance structures to keep up with changes in technologies, societal preferences, business use cases, environmental considerations, and other factors that have changed over time. Some of these agreement-specific mechanisms take the form of annual or regular meetings at which binding and non-binding decisions can be made. Of the space-specific treaties and frameworks noted in this report, only the ITU has such a mechanism, which has probably contributed to the union's longevity.

BUILDING LUNAR INFRASTRUCTURE

Improving cislunar infrastructure can optimize U.S. cislunar efforts, particularly activities aiming for a long-term, sustained presence on the lunar surface. Specifically, NASA's vision for the Moon will require processes and systems that can provide power and communications, protect electronics and humans from radiation, provide positioning and navigation services, collect cislunar SSA information, manage cislunar space traffic to minimize spacecraft collision risks, and mitigate the risks to lunar operations from regolith dust.

Many planned lunar activities will happen in the same areas, specifically in the south pole, so there will be a need for one nation's systems to coexist near other nations' missions. Effective solutions for this issue are not primarily technical ones but depend on the development of coordination mechanisms and baseline agreement regarding how to behave on the Moon and in lunar orbit. Improved coordination mechanisms between spacecraft operators, both transiting space between GEO and the Moon and in lunar orbit, would likely go a long way toward mitigating the threat of cislunar spacecraft collisions and minimizing risks of new debris creation.[239]

As noted, efficiently supporting upcoming U.S. lunar activities will require certain technological solutions, including communications, power, and navigation and positioning information. Though the United States, ESA, China, and other spacefaring entities can continue to pursue their own cislunar goals, there is an opportunity to address infrastructure challenges using an international model. The United States is already thinking internationally by developing the LunaNet communications framework, an open-architecture approach intended to facilitate allied collaboration around lunar connectivity.

There are several helpful examples for structuring international cooperation in space. One is the ISS model, which assigned responsibilities for the provisions of certain space-station components to individual countries. A nearly identical model is the Artemis program, which trades opportunities to fly payloads and astronauts on Artemis missions for equipment, systems, and components provided by other countries for use in the Artemis architecture and Lunar Gateway. Notably, other than the UAE, all other nations contributing to the Lunar Gateway are also ISS partners. A third model is ESA's Ariane project, which led to the development of the Ariane 1 rocket and creation of Arianespace, a company that operates this family of launch vehicles.

It is worth taking a closer look at the approach used for the Ariane project, which is the same way that ESA funds and manages all its projects. For the original Ariane project, about 10 partner nations pooled funds and assigned one organization to act as project manager.[240] Each partner nation signed up for the project knowing it would receive a certain rate of return on national funding provided to the project. Specifically, domestic firms in each partner country received contracts totaling 80 percent of the amount

Figure 8: Selected Planned Activities in the Lunar South Pole Area

Source: Authors' research based on multiple sources.

EXPECTED LAUNCH YEAR	MISSION NAME	COUNTRY OF ORIGIN
2025	Intuitive Machines 2 - Athena, CLPS Mission	United States
2025	Griffin Mission 1 (Astrobotic), CLPS Mission	United States
2025	Lunar Surface Access Service 1 (LSAS-1)	Germany and Israel
2025	Lunar Polar Exploration Mission (LUPEX)	Japan and India
2025	Blue Moon Mark 1 (Blue Origin), Uncrewed Demonstration	United States
2026	Artemis III	United States
2026	Flexible Logistics and Exploration (FLEX) Mission 1 (Astrolab)	United States
2026	Chang'e 7	China
2026	Starship Human Landing System (HLS) Uncrewed Demonstration	United States
2026	Starship Human Landing System (HLS) Crewed Demonstration	United States
2028	Chang'e 8	China
2030	Artemis IV	United States
2035	International Lunar Research Station	China and Russia
TBD	Blue Moon Mark 2 (Blue Origin)	United States

invested by their governments.[241] This approach allows partners to invest in their own domestic industries and pool resources for greater impact.

There are several benefits to modeling an effort on the Ariane project for building and operating lunar infrastructure. The first is that it allows for cost sharing across many nations interested in developing and using lunar infrastructure for their own national efforts. If there were commercial use cases for developing such infrastructure on the Moon, there would be no need for an international, government-sponsored activity, as market forces would be driving the development of lunar infrastructure. But government missions and missions primarily supported or subsidized by government funding are the only real customers for lunar infrastructure services. An international, government-funded and -driven approach would thus ensure the final product matches space agencies' science and exploration needs.

Another benefit to an internationalized initiative is that it could attenuate national pressure to compete for certain lunar real estate, such as peaks of eternal light (ideal for solar power infrastructure) or Earth–Moon Lagrange points (ideal for communications nodes). Internationalized cislunar architecture could also be an anchor for peaceful coexistence in space, just as the ISS maintains a peaceful link between the United States and Russia today. Finally, an international approach can be structured to provide benefits to national industries. The Ariane 1 and ESA models guarantee national governments' return on investment that gets funneled directly back to their domestic industrial bases. The ISS and Artemis programs, while structured differently, do the same thing. These models effectively offer protectionist returns to domestic industries while pursuing international collaboration.

IMPROVING OPERATOR COORDINATION AND DATA SHARING

Ideally, new cislunar monitoring infrastructure, possibly comprising systems on Earth and the Moon as well as spacecraft in cislunar space, will provide comprehensive SSA services for operators of cislunar spacecraft. Infrastructure could also provide positioning and tracking data about spacecraft and human-made systems operating on the Moon's surface. There are plans in the next 10 years to build and launch space systems to collect SSA data in cislunar space. One or two SSA data-collecting satellites, however, would only be able to provide coverage on a very small portion of cislunar space—just a drop in the ocean.

Building robust and comprehensive SSA infrastructure will be costly and take time. As noted in the previous section, one idea to address this need would be to create an international partnership to build cislunar infrastructure, such as an SSA network. The authors of this report think this approach has merit but recognize that it would take time to negotiate and establish the foundations for an internationalized cislunar infrastructure operator, effectively equivalent to a lunar public utility company.

In the meantime, something should be done to reduce the risk of collisions for spacecraft operating in cislunar space, including in lunar orbit. There is also a need to coordinate activities on the lunar surface, particularly in the Moon's south pole due to the amount of expected activity there (see Figure 8). Even with the paltry number of active spacecraft orbiting the Moon—only about a handful today—there are increasing collision risks.[242] Fortunately, unlike orbits closer to Earth, there are very few known human-made debris objects or fragments in cislunar space and only one recent example of human-made debris unintentionally hitting the Moon's surface.[243] International agreed-to rules and norms on mitigating the creation of cislunar debris—accepted by both the United States and China, as well as other lunar operators—could go a long way in protecting the cislunar environment from new human-made debris.

One way to address both cislunar space traffic coordination and deconfliction and prevent the creation of new cislunar debris is to incorporate these elements into international space governance frameworks. Though the authors of this report believe that negotiators and diplomats, especially U.S. and Chinese ones, can ultimately find common ground on these and other space governance issues, the authors recognize this may take time. Until then, cislunar governmental and private sector spacecraft operators from all nations can do a lot on their own, taking matters somewhat into their own hands.

Spacecraft operators can vastly reduce the risk of collisions and events that could cause new cislunar debris by increasing coordination and data sharing. No operator wants its satellite to collide with another or to hit a piece of space debris, so arguably all operators share a common goal, one of self-interest.

> *Spacecraft operators can vastly reduce the risk of collisions and events that could cause new cislunar debris by increasing operator-to-operator coordination and data sharing.*

Outside of diplomatic channels or government-to-government negotiations, operators and other space stakeholders from the United States, China, and other nations are working together in forums such as the Consultative Committee for Space Data Systems and International Organization for Standards to establish mechanisms and best practices for improved information sharing. These efforts are not tied specifically to cislunar space, but to space operations more broadly and touch on issues such as data standards, sharing spacecraft position information, and operator notification procedures to forestall collisions. Such discussions could eventually include elements important to cislunar operators, particularly considerations for landing and launch from the Moon's surface and measures to prevent the creation of new cislunar debris. These discussions can also help build trust between U.S. and Chinese space stakeholders.

MILITARY USE AND NATIONAL SECURITY

Outer space up to GEO is widely used for military purposes, with significant national security equities in those regions of space. The U.S. military relies on space to fight and win wars, with satellites between LEO and GEO performing all or parts of critical missions, such as navigation, missile warning, and communications. Additionally, the U.S. economy depends on space, with power utilities, communications networks, and financial institutions using precision timing derived from GPS satellites. Commercial air travel is increasingly dependent on GPS. Many American households, businesses, and first responders use satellites for broadband connectivity. In these regions of space, the United States has many reasons to protect and defend its equities—which do face counterspace threats.

But beyond GEO, things start to look very different. There are no current cislunar assets that enable joint operations. The United States would gain no clear strategic military advantage over China or any potential adversary from military activities in cislunar space. No technology that could be conceivably deployed within the next few decades could influence military outcomes on Earth. There is also no appreciable economic activity or national presence to defend and protect other than initiatives focused on science and exploration. Though future human habitation or significant economic activities on other planets could change these dynamics, there is no sign this will happen anytime soon. If the military needed SSA data on cislunar space, it could obtain that from systems operated by civilian or commercial entities.

Every dollar the U.S. military spends on a cislunar-focused project is a dollar taken away from another effort that likely has more effect on U.S. national security. In particular, if U.S. defense and military officials are concerned about fielding capabilities to deter and address threats from China by 2027, any resources spent today on cislunar national security capabilities could be better spent elsewhere.[244] Nothing the U.S. military deploys to cislunar space can help win a war on Earth, whether with China or anybody else. Technological developments and other circumstances could cause a reevaluation of this calculus, but that does not rule out the consideration that a nonmilitarized cislunar space is the right answer now. And "right answer now" means "for the foreseeable future"—a span measured in many decades. In the far distant future, realistic plans for human colonies on the Moon and other planets, lunar economic equities threatened by space piracy, cislunar deployment of weapons of mass destruction targeting Earth or non-Earth locations would mean reevaluating the wisdom of keeping military activities out of cislunar space.

The United States faced similar considerations regarding Antarctica in the 1950s. At that time, Washington was concerned that the Cold War could extend to Antarctica, sparking both a territorial land grab and race to establish military dominance there. Smartly, the United States saw no benefit from that development and worked diplomatically to preserve the status quo, which meant keeping military activities out and preserving the region for scientific research. Fortunately, the Soviet Union agreed to insulate Antarctica from military activities as long as it could be a party to the negotiation and subsequent agreement. It is critical to highlight that this arrangement only worked because the United States gave the Soviet Union a seat at the negotiating table.

Both the United States and China talk publicly about national security considerations for cislunar space. But the core considerations on both sides are national prestige and fears about getting shut out of cislunar opportunities, rather than strategic military advantage.[245] As with Antarctica, it may be better for the United States and China to keep military uses and activities away from cislunar space for as long as possible.

What happens if the United States seeks to preserve the nonmilitarized cislunar status quo through an agreement with China and other nations, with compliance monitored via new civil and commercial cislunar SSA capabilities? Achieving this outcome would free up U.S. defense funding and resources for better use elsewhere, possibly on other military space capabilities closer to Earth. China, like the Soviet Union regarding Antarctica, might be receptive to preserving a nonmilitarized cislunar environment. But if China does not agree on that goal, the United States should let China waste resources. Every renminbi spent on a Chinese military cislunar development—to win a race that would grant it no strategic advantage—is a renminbi not spent on some other system that could truly harm U.S. national security. For the foreseeable future, nothing China could do in cislunar space would alter the military calculus on Earth should it ever find itself in a direct conflict with the United States.

In the interest of optimizing the use of military resources, the United States may want to consider whether DoD cislunar programs, such as those at DARPA and AFRL, should be funded from the defense or non-defense budgets.

Programs like AFRL's Oracle-Mobility and Oracle-Prime are designed to test cislunar SSA and tracking technologies, which could support civilian and commercial cislunar activities and align with NASA's cislunar infrastructure needs. There is no reason such programs could not be managed and funded by NASA or another civilian agency. Additionally, the U.S. government could contract with companies, who could build and operate commercial systems, to provide cislunar SSA data and services. Alternatively or concurrently, the United States could undertake an international approach to building such cislunar infrastructure. In either case, DoD and other national security users who want SSA data for cislunar space domain awareness, such as for monitoring China's cislunar activities, could obtain such data from civilian or commercial systems.

RECOMMENDATIONS

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Based on the preceding observations on potential paths forward, the authors offer the following recommendations for consideration by U.S. policymakers:

Address governance gaps and coordination with China: To create a safe and sustainable cislunar environment so that the United States can achieve its national objectives, the United States should address cislunar space governance and coordination gaps in a manner that includes input from China. These governance gaps include agreement on permissible activities, property rights and space resources, and space rules of the road. Additionally, the United States should work with China to increase operator-to-operator data and information sharing related to space safety. Other nations should be included, but coordination protocols and governance agreements and principles negotiated without China are not worth the time. Ideally, solutions to address these issues for cislunar space can address these issues across all of space too.

There are several possible approaches that could be used by the United States to address cislunar governance gaps. An approach modeled on the Arctic Council—not a treaty but an intergovernmental agreement—could provide a body through which the United States and China, as well as other spacefaring nations meeting certain membership criteria, could discuss cislunar space governance and coordination. As with the Arctic Council, this approach would exclude direct involvement with the United Nations and its full membership. In taking the first steps in establishing such a cislunar space council, the United States could look to the Ottawa Declaration, which established the Arctic Council, for guidance. An International Lunar Year conference—already being discussed by the United States—could also aim to facilitate discussions on cislunar governance among nations with lunar equities. Should it pursue any of these paths, the United States could base its negotiating positions on the Artemis principles. But as the report's authors have already noted, it is not realistic to expect that China would sign the Artemis Accords, since it was not consulted during their formulation.

Additionally, the United States could try to find consensus with China on cislunar coordination issues through UN arrangements such as the ATLAC. As noted in an earlier section, this action team was established to provide a forum for U.S.-Chinese discussions on cislunar space coordination. Ultimately, a modest goal for the ATLAC may be to build trust between the two powers. Trust is needed for both sides to grow more comfortable directly engaging with each other on cislunar space safety, coordination, and governance issues—and later in drafting more comprehensive agreements on broader space governance, coordination, and safety issues.

Ensure nonmilitarized status: The United States should assess whether there are compelling strategic cislunar military uses or goals. The authors of this report assert that this report do not see any now or in the foreseeable future and assert that cislunar space looks like Antarctica did in the 1950s. If it does not foresee any strategic national security objectives, the United States should advocate for the same approach taken in Antarctica, meaning no military uses of cislunar space, reinforcing the OST provisions already prohibiting military activities on the Moon and other celestial bodies. This would require an agreement between the United States and China, ideally including other spacefaring nations, to keep military interests out of cislunar space. Such an agreement could be negotiated outside of the United Nations, mirroring the approach taken for the Antarctic Treaty. Arguably, this process could proceed hand in hand with the first recommendation in this section, meaning that part of the effort to create a cislunar space council might involve efforts to ensure the nonmilitarized status of cislunar space. This approach does not rule out U.S. national security interest in monitoring cislunar space and assumes DoD and other national security users could acquire cislunar SSA data from civilian or commercial sources for such purposes.

Pursue international collaboration on infrastructure: Solutions to address cislunar infrastructure requirements can best be addressed internationally by pooling resources and creating shared capabilities that potentially lessen the motivations for friction over desirable lunar real estate such as the peaks of eternal light. An international approach that allows partner nations to earn returns on their investments and support domestic industries provides an incentive to participate. The Ariane project offers one model for consideration. Such internationalized infrastructure could help preserve the peaceful, scientific use of the Moon and cislunar space, creating a strong foundation for the United States and other nations to pursue their scientific research and exploration goals. Shared international ownership of cislunar architecture could also form the sinews of peace between nations with cislunar activities, even in times of tension. Arguably, the ISS has served that purpose, remaining one of the last places of peaceful collaboration between the West and Russia over the past two years. Future internationalized cislunar infrastructure could serve the same purpose and advance not only U.S. national interests, but the interests of all humankind.

The report's authors also want to reiterate a few things that the United States does *not* need to do. There is presently no need for a specific U.S. cislunar strategy or national security cislunar strategy. Existing U.S. space goals and strategy documents are sufficient, though U.S. government implementation plans will prove useful. While investments in new cislunar SSA technologies and systems are important, improved coordination mechanisms and operator data sharing can vastly improve cislunar space safety and sustainability. Incremental steps today to improve cislunar SSA data collection are sufficient to meet the anticipated traffic, giving the United States time to develop a holistic and thoughtful architecture for a future cislunar SSA network. Taking steps to create agreed-to rules to prevent the creation of new cislunar space debris further lessens any urgency to build cislunar SSA infrastructure. Additionally, there is no need for U.S. military projects focused on cislunar space.

Ultimately, the authors acknowledge that these recommendations—collaborating with China, limiting military activities beyond GEO, and internationalizing lunar infrastructure—challenge aspects of conventional U.S. thinking on space. This means that implementing one or all of these recommendations will require significant political will. But the United States should not be afraid to make a course correction resulting in an outcome that better aligns with U.S. interests, even if that path seems hard.

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"We choose to go to the Moon. . . . We choose to go to the Moon in this decade and do the other things, not because they are easy, but because they are hard."

— President John F. Kennedy, 1962[246]

CONCLUSION

There is a lot of promise—and hype—around the future of humankind in cislunar space. But there are also hard realities. Only the United States and China are positioned to develop and launch crewed spacecraft to the Moon. Russia has ambitious plans for crewed lunar missions but insufficient resources to make them happen. Without the United States and China, there would be very few missions to cislunar space over the next decade. Several other nations are planning uncrewed missions to the Moon, but most of these missions are hitching a ride on a U.S. spacecraft. While some of these future missions will be operated by companies, they are still inextricably tied to government funding and objectives—particularly to NASA funding. Today, there are few, if any, realized business cases separate from the government for cislunar activities.

Almost all activities in cislunar space, including in orbit and on the surface of the Moon, focus on science and research. As with Antarctica, there is no clear or obvious strategic military benefit derived from cislunar space. Militarily "winning" in cislunar space, no matter how one defines it, would do nothing to alter the outcome of a conflict between the United States and China—or any other possible adversary. Military funding and resources can be better spent elsewhere. It is in the interests of the United States to keep military uses out of cislunar space as long as possible and to retain the focus on science, leaving open the door to future business use cases such as mining.

There is no indication of a lunar gold rush, though cislunar traffic has steadily increased since the 1980s. If there is one area of increased activity deserving of attention, it is the lunar south pole. There will likely be more overlapping activities from various nations at the lunar south pole than anywhere else on the Moon. Governments' investments in technologies and infrastructure and their efforts to address space governance gaps should be aimed at making sure that activity in this region and in lunar orbits can be done safely, sustainably, and efficiently. Given that the current focus is science and exploration, the United States should continue to collaborate with partners worldwide, potentially taking an international approach to building and operating cislunar infrastructure to meet these goals. Furthermore, the United States should try to collaborate with China, particularly on cislunar space governance and operational space safety coordination.

The current geopolitical environment makes it harder to work collaboratively with China. The Cold War provided a similarly tense environment—yet it was against this backdrop that the United States, Soviet Union, and dozens of nations produced the OST and several subsequent space agreements. This context produced the Apollo-Soyuz mission, laying the groundwork for the ISS decades later. Cislunar space and beyond is probably the best environment—maybe the only environment today—where the United States and China, as well as many other nations, can find common ground on shared interests. The United States should seize this opportunity, both for U.S. national interests and for humankind more broadly.

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