MOONSTRUCK! INTERNATIONAL ASPIRATIONS IN CISLUNAR SPACE

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Executive Summary

Interest in cislunar space is increasing, both nationally and internationally. For the purposes of this chapter, cislunar space is defined as that volume of space above geosynchronous orbits, including the Earth-Moon Lagrange point regions and the lunar surface. In the United States, NASA has the lead in exploration and science while the U.S. Space Force and U.S. Space Command are out front protecting national security interests. Commercial space companies are interested in cislunar space because of possibly valuable resources that might be profitably harvested from the Moon. Internationally, the People's Republic of China (China), India, Japan, South Korea, the United Arab Emirates (UAE), Israel, and Russia have plans for lunar robotic missions. The United States, China, and India are planning human landing missions with the United States and China aiming to establish crewed lunar science and research stations. It is imperative that the United States develops capabilities to monitor, track, and assess these activities to protect our national interests and assets. The overarching issue is governance and establishing operational norms of behavior. Three recommendations are proffered based on the research findings detailed in this chapter:

1. The United States should continue to invest in lunar exploration and exploitation aimed at establishing foundational interoperable cislunar infrastructure in concert with public relations and education campaigns.

2. The United States must establish and then enhance its cislunar situational awareness capabilities, which will be crucial to the success of lunar orbital and surface missions.

3. The United States must take a leadership role in establishing and contributing to governance agreements and international norms of behavior to promote sustainable science, exploration, and resource utilization and to protect personnel working in cislunar space.

If the United States maintains its enthusiasm and motivation to push cislunar development forward on the civil, commercial, and security fronts, it has the possibility of maintaining its leadership in space. If there is a path to cooperation, or at least a healthier "coopetition," the nation should take the initiative to lead humanity in that direction.

Introduction

There is a burgeoning interest in cislunar space across a broad range of players, both nationally and internationally, with wide-ranging goals and aspirations.[1] NASA is leading the charge on the civil front for the U.S. government (USG) through its most visible activity, the Artemis campaign, aiming to land U.S. astronauts on the Moon in the late 2026 time frame with an eye toward preparing for future crewed Mars missions. In support of Artemis, NASA is also sending robotic missions to explore the Moon both on the surface and from lunar orbit. As part of Artemis mission architecture, NASA is leading the international Gateway program to build a space station orbiting the Moon. The science community also has shown substantial interest as the Moon presents a unique environment in which to conduct research to help us better understand the origins of our planet and the universe.

NASA is not the only entity interested in the Moon. From the standpoint of protecting national interests on and around the Moon, it is in the interest of the United States to monitor, track, and understand the current and future activities of competitor nations, a task that is now in the remit of the U.S. Space Force and the U.S. Space Command. Concerns in the national security community are elevated because several other countries have already executed missions both in lunar orbit and on the surface, with plans for more. Commercial interest is also high because evidence points to water ice in the lunar southern polar regions, which could potentially be used to make oxygen and rocket fuel on the Moon. Finally, commercial space sees the potential for lunar infrastructure construction and the harvest of other valuable resources, such as rare earth metals, if a cost-effective process is developed.

On the international front, countries including India, Japan, South Korea, the United Arab Emirates (UAE), and Israel have executed or plan to execute lunar robotic missions, with India planning a crewed landing on the Moon by 2040.[2] The People's Republic of China (China) is leading the way with recent successful missions to the surface of the Moon. In June 2024, following on the heels of the Chang'e-5 lunar sample return mission, the Chang'e-6 mission became the first ever to return lunar material from the far side of the Moon.[3] China has big plans for cislunar space, including landing humans on the Moon by 2030.[4] China and Russia have partnered on developing the International Lunar Research Station (ILRS)[5], which now includes 13 countries and a number of other institutions, that will be a research outpost on the lunar surface near the south pole. China's rapid advancement in space technology and exploration is a concern to many in the national security sector.

It is important to understand where in space the United States and other countries and coalitions will be operating in the near future and why cislunar space is so attractive. This chapter provides a description of what comprises cislunar space, identifies reasons for the heightened interest in cislunar space, summarizes the main players and their aspirations, and highlights both uncrewed and crewed missions through the 2040 timeframe. The chapter concludes with observations on the state of play in cislunar space as well as recommendations for actions the United States should undertake to ensure space leadership and influence in the development and use of the emerging cislunar ecosystem.

What and Where Is Cislunar Space?

There are competing definitions of cislunar space.[6] US Code, Title 42, Section 18302 defines cislunar space as "the region of space from the Earth out to and including the region around the surface of the Moon."[7] One of several NASA definitions states that cislunar space is that area of deep space under the gravitational influence of the Earth-Moon system including all Earth-centered orbits, low lunar orbits, and the Earth-Moon Lagrange points (Ls), which are the locations in space where the gravitational forces of Earth and the Moon are essentially balanced.[8] In other words, cislunar space is the volume of space extending from the surface of Earth to beyond Earth-Moon Lagrange point 2 (L2).

Figure 1 is a simplified diagram showing Earth in the center, the geosynchronous Earth orbit (GEO), the Moon's orbit, and locations of the five Earth-Moon Ls. If a spacecraft is positioned in orbit about an L, then it can operate there with very little propulsion required for station keeping. Of particular interest for lunar operations are L1 and L2 regions given their proximity to the Moon. For example, the L2 region is ideal for placing communications satellites for missions operating on the far side of the Moon. Cislunar space is not a flat planar geometry—it's a huge volume in space, more than 1,000 times larger than the volume of space below GEO.

Policymakers define cislunar space in the 2022 *National Cislunar Science & Technology Strategy (NCSTS)*.[9] "Cislunar space is the three-dimensional volume of space beyond Earth's geosynchronous orbit that is mainly under the gravitational influence of Earth and/or the Moon. Cislunar space includes the Earth-Moon Lagrange point regions, trajectories utilizing those regions, and the lunar surface." Unlike NASA's definition, cislunar space as defined by the NCSTS is the region excluding below GEO but adding the lunar surface. The reason for excluding orbits closer to Earth below GEO is that Earth's gravity overwhelms that of the Moon in this region; the gravity level on the surface of the Moon is one-sixth that at Earth's surface. As a spacecraft moves beyond GEO, lunar gravity has a greater effect on its trajectory as it moves further from Earth and closer to the Moon.

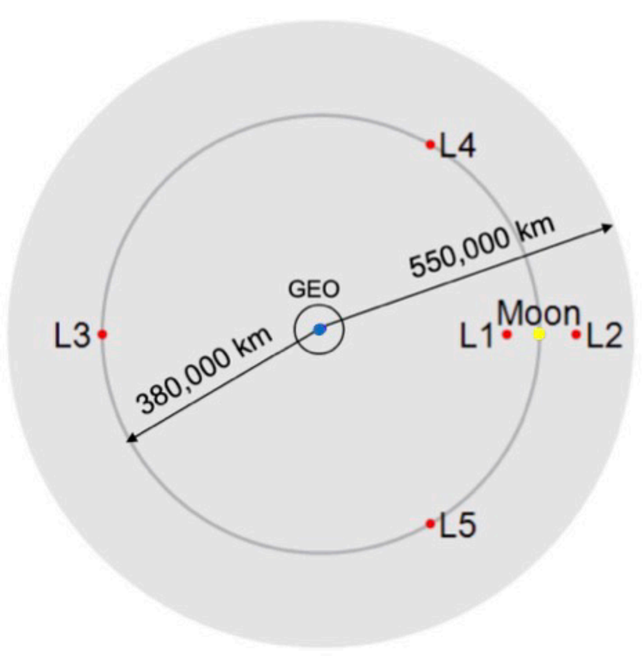


Figure 1. Cislunar space.

Figure 2 is a more complex diagram of cislunar space. It shows the low Earth orbit (LEO) of the International Space Station (approximately 400 km altitude), a GEO orbit, and halo orbits around L1 and L2 where future spacecraft will operate. The diagram also provides a figurative depiction of the gravitational strengths of Earth and the Moon, or their gravity wells. The "deeper" in the gravity well, the more energy is needed for an object to depart for another location. The gravity well for Earth's surface is deepest, the ISS next, and so on. Note that orbits about the Lagrange points are quite shallow and can serve as efficient departure points to visit either Earth or the Moon.

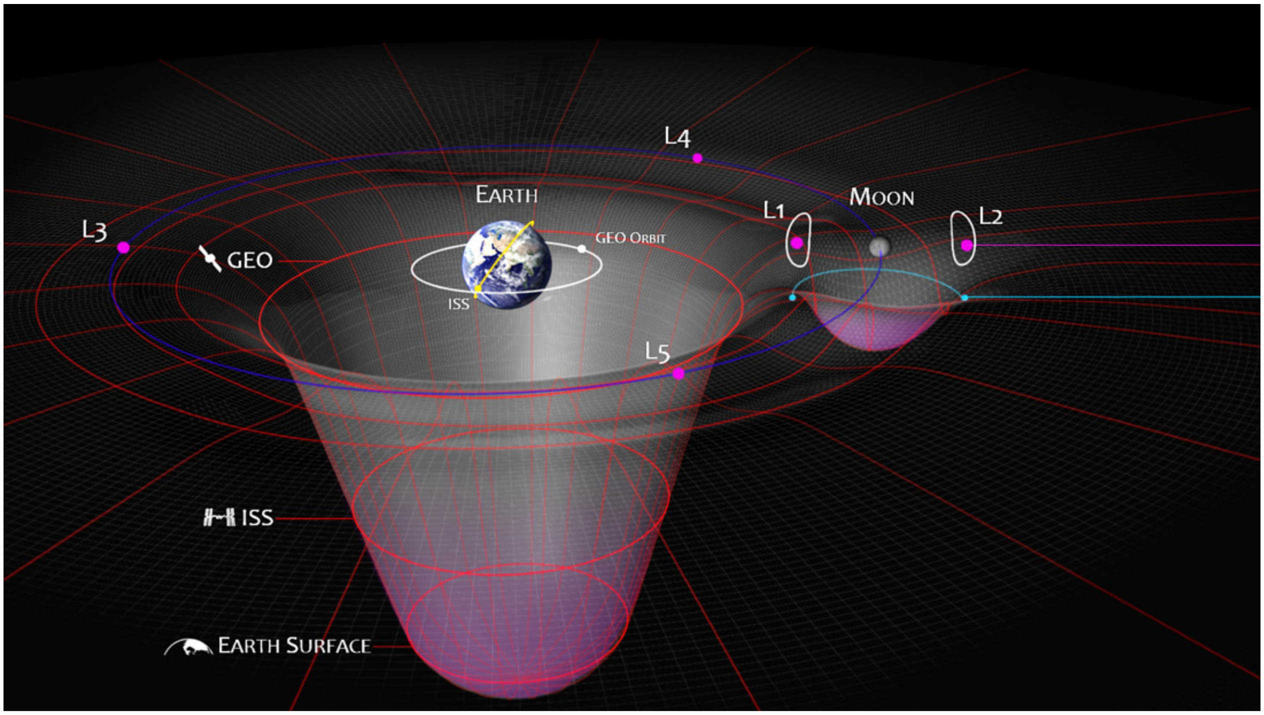


Figure 2. Depiction of cislunar space (not to scale). *(Source: NASA)*

Why Is There So Much Interest in Cislunar Space?

When NASA confirmed the existence of lunar ice in the permanently shaded regions of the Moon in 2018, the idea that humans might be able to survive and even thrive on the Moon significantly enhanced the prospects for lunar exploration and exploitation.[10] Lunar ice could be used to produce water to drink or irrigate crops or be separated into oxygen to breath and hydrogen to use as rocket fuel. Being able to produce propellant on the Moon would open many possibilities for exploration beyond lunar orbit as the launch energy required to reach other places in the solar system is reduced. Based on the *rocket equation,*[11] the amount of energy required to leave Earth's gravity well is about six times more than to leave the lunar gravity well.

All these possibilities have stimulated a confluence of global international interest in leveraging cislunar space in the areas of exploration, science, commercial enterprise, and security. There are interdependencies among these four areas offering the opportunity for synergistic projects and programs.[12,13] In other words, a program aimed at exploration may also yield results or technology beneficial to the commercial space sector or vice versa. The four strategic objectives in the 2022 NCSTS support these enterprise areas and call for international cooperation and extended space situational awareness capabilities. The NCSTS seeks to foster a viable cislunar ecosystem through supporting and stimulating U.S. government, academic, and commercial cislunar activities, consistent with the U.S. Space Priorities Framework.[14]

National Cislunar Science & Technology Strategy

The NCSTS is the first interagency strategy aimed at guiding U.S. governmental actions in cislunar space. It supports the U.S. Space Priorities Framework in which it is stated that the United States will "advance a robust cislunar ecosystem."

The four strategic objectives of the NCSTS are:

1. Support research and development to enable long-term growth in Cislunar space.
2. Expand international S&T cooperation in Cislunar space.
3. Extend U.S. space situational awareness capabilities into Cislunar space.
4. Implement Cislunar communications and position, navigation, and timing (PNT) capabilities with scalable and interoperable approaches.

Exploration. Since the United States last landed humans on the Moon in the early 1970s, there have been numerous NASA programs initiated to return humans to the Moon.[15] These have fluctuated with presidential administrations; however, the NASA Artemis missions to return humans to the Moon[16] have endured two administrations. While the long-term goal is to establish sustainable permanent lunar settlements and drive cislunar economic development, the Moon is also seen as a proving ground to pave the way for sending humans to Mars. Both China and India have set their sights on landing humans on the Moon by 2030 and by 2040, respectively.

Science. The Moon offers a unique opportunity to perform both fundamental and applied scientific research in the areas of planetary science, astrophysics, biophysics, solar physics, solar system evolution, and even Earth sciences. Cislunar space affords an environment in which to execute research in trajectory planning, navigation, and control to improve object tracking and position determination and prediction capabilities. Lunar surface processes can be studied in situ to better understand volatiles distribution and the cooling and crystallization of the Moon's upper mantle. The environment of cislunar space provides an ideal testing ground to study the effects of space radiation on humans and hardware. Moreover, it may be possible to perform radio astronomy observations that are not possible anywhere else in the vicinity of Earth from a lunar zone that is shielded from radio frequency interference known as the shielded zone of the Moon (SZM).[17]

Commercial Enterprise. To establish outposts on the lunar surface, a substantial amount of infrastructure will be required. This presents opportunities for the commercial space sector to provide hardware and software services for needed functions such as communications; positioning, navigation, and timing (PNT); power; propellant; surface transportation and mobility systems; and space situational awareness capabilities.[18] See Figure 3 for more examples. Other commercial opportunities include in-situ resource utilization (ISRU) and the potential to harvest water, helium-3, rare earth metals, and regolith that potentially have value on both the lunar surface and back on Earth.[19] In fact, the formation of a company to harvest helium-3 (a useful element that is rare on Earth) from the lunar regolith and bring it back to Earth was recently announced.[20,21] A startup company has also recently demonstrated the application of robotic technology to construct a five-meter tower that could be used for lunar communications systems.[22] NASA has established the Commercial Lunar Payloads Services (CLPS) Program, leveraging commercial landers to deliver both governmental and commercial science and technology payloads on or in orbit around the Moon.[23] Not until a solid business case can close around such ventures will commercial enterprise be motivated to participate. Companies follow the money.

Security. With growing interest in the cislunar region and the lunar surface for scientific and commercial developments, there will be a growing desire to protect those investments. Concerns

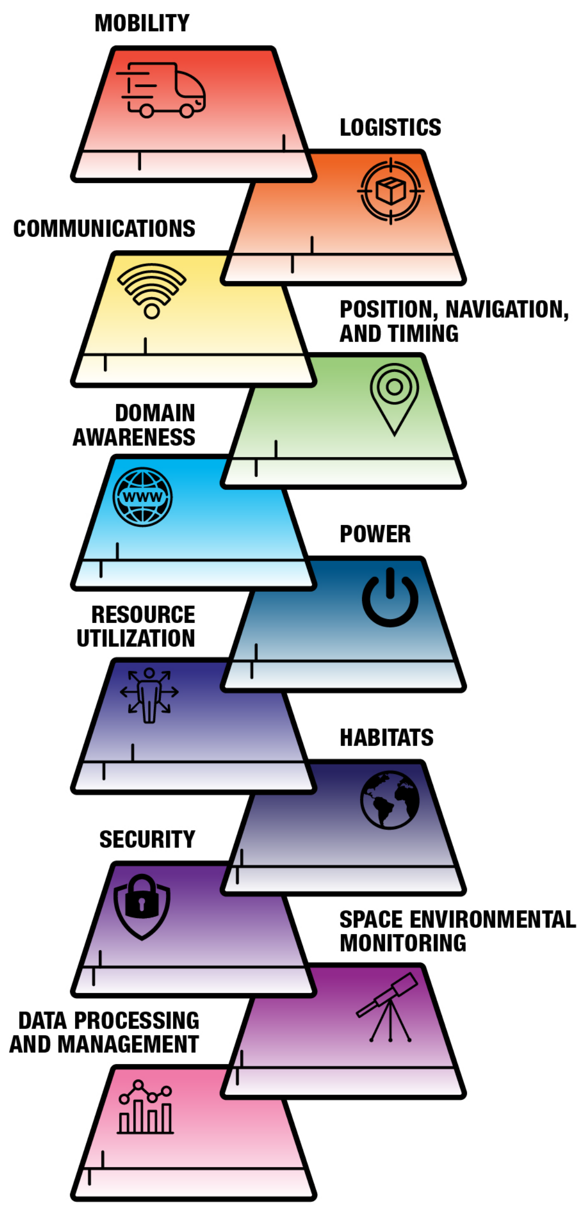


Figure 3. Cislunar infrastructure opportunities.
(Source: Guidi et al., 2022)

include dual-use technologies, orbital surveillance, trusted communications, and limited interference. One area of great need is increasing space situational awareness (SSA) to help ensure safety and security in the region for all players. Obtaining and maintaining cislunar SSA is challenging because of the sheer volume, which dwarfs (by over a thousandfold) that enclosed by GEO. Not only distances but also finding objects in cislunar space is further complicated by unpredictable orbits,[24] solar reflection off the Moon, keeping sensors in the correct orientation relative to the Sun, and a lack of continuous coverage from Earth.[25] Areas where SSA infrastructure can be placed include lunar bases (especially on the lunar far side), stable lunar orbits (elliptical, high altitude, and inclined), halo orbits around Lagrange points (Ls 1, 2, 4, and 5), and transit orbits between Earth and the Moon. In the United States, consistent with Objective 3 of the NCSTS, the Air Force Research Laboratory (AFRL) is developing the Oracle family of systems comprising two programs, Oracle-Mobility (Oracle-M) and Oracle-Prime (Oracle-P), which are designed for cislunar SSA to provide the foundations for safe operations in cislunar space in support of responsible and sustainable lunar exploration.[26] In the future, it is likely that security concerns similar to those on and around Earth will propagate into cislunar space.

Governance. The capstone to all the above interests—exploration, science, commercial enterprise, and security—is governance. While no single nation has governance over cislunar space and the Moon, there are efforts to provide frameworks for protecting the interests in cislunar, for example, the Artemis Accords.[27] Moreover, the foundation of any governance or pursuit of normative behavior in the cislunar region is situational awareness—or the basic element of security interests in the region.

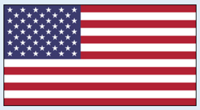
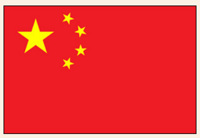
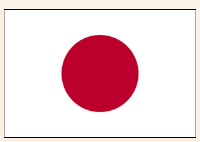
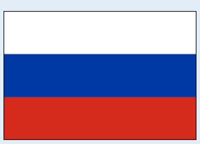
Science, exploration, and commercialization efforts involve time and money, be they from the public or private sector; therefore, any normative behavior that protects safe operations also protects those investments. When considering successful commercial enterprise, it is recognized that would-be investors are more attracted to stable environments, making this essential for a future cislunar market economy where government is one of many customers.

While creating a universal, stabilizing operational framework will need leadership and diplomacy, it also heightens safety and security interests in the region. Foremost is protecting the free movement of entities without endangering other users in transit, in orbit, or on the lunar surface. The protection of commercial surface operations, such as mining or ground stations, against endangerment from close-proximity operations, intentional cyber damage, or spectrum interference is of primary concern. One might even include protection of heritage sites from unintentional damage, like that of the Apollo 11 lander.

Which Nations Are the Main Players?

Even with the elevated level of interest in cislunar space demonstrated over the last 20-plus years, there are only a handful of main players involved in its development through history. The United States is the only country to have landed humans on the Moon with the last Apollo mission completed 52 years ago, followed by a spattering of robotic and orbital flyby missions by the United States, the Union of Soviet Socialist Republics (USSR), and Japan. Since late 2010, there have been 24 lunar missions comprising flyby, orbital, impactor, and landing scenarios executed by the United States, China, Japan, India, South Korea, Israel, Russia, and the European Space Agency (ESA). Other spacefaring nations that have sent payloads or independent orbiters as ride shares include Luxembourg (with China), Italy (with the United States), the UAE (with Japan), Mexico (with the United States), and Pakistan (with China). Not all of these recent missions have been fully successful, but the broadened international interest in space is apparent.[28, 29]

Table 1 summarizes aspirations of the main players in cislunar space exploration as gleaned from the references cited thus far that address plans for cislunar development.[30]

Table 1: Aspirations of the Main Players in Cislunar Exploration	
Main Players	**Cislunar Aspirations**
United States 	• Continue lunar robotic missions through the NASA CLPS Program • Stimulate commercial participation in the development of cislunar space • Land humans on the Moon in 2026 on Artemis III • Build the Gateway space station in lunar orbit • Establish Artemis base camp for longer lunar surface expeditions
China 	• Continue exploration progress with the Chang'e-7 and Chang'e-8 missions • Continue to expand communications infrastructure building on the Queqiao-2 relay satellite (successfully used in Chang'e-6 mission, planned for use in 7 and 8) • Land humans on the Moon in 2030 • Lead the development of the International Lunar Research Station, a permanent research base, with support from its signatory countries
India 	• Continue lunar robotic exploration with Chandrayaan missions 4–7 • Crewed Gaganyaan orbital missions • Implement lunar cruiser missions to NASA-led Gateway space station • Use Launch Vehicle Mark 3 Launcher for human Moon landing by 2040
Japan 	• Collaborate with NASA on Gateway space station and provide lunar terrain vehicles and rovers • Launch LUPEX lunar lander/unpressurized rover to south pole (with India) • Send Japanese astronaut to the lunar surface on Artemis V
Russia 	• Continue Luna series of landers and rovers • Participate with China in the International Lunar Research Station

Human landings are part of plans for the United States (2026), China (2030), India (2040), and Japan as part of Artemis. China is planning and partnering for the ILRS on the lunar surface, while the United States and partners are focusing on the robotic Gateway lunar space station that will be integral to the Artemis human missions. India will build on its success as the first country to land an uncrewed rover at the lunar south pole, and partner with Japan on a lunar lander.

Announced and Projected Uncrewed Cislunar Missions Through the Early 2030s

A plethora of cislunar missions is planned from now until the early 2030s. According to BryceTech,[31] there have been 131 uncrewed cislunar missions announced or projected for 2024 through 2033. Of the total, 83 are planned by the United States with the 48 international cislunar missions planned by 16 countries plus ESA.

Table 2 summarizes the U.S. mission breakdown by mission name, number of planned missions, and mission type. Table 3 does the same for international missions by country. A database of cislunar missions (see reference) has also been developed and is kept current.[32]

Table 2: Uncrewed U.S. Cislunar Missions 2024–2033		
U.S. Missions	**Number**	**Lunar Mission Types**
NASA Lunar Gateway Habitat and Logistics Outpost/Power and Propulsion Element	1	Orbiting space station core (Gateway)
NASA Lunar Gateway Airlock	1	Orbit
Commercial Gateway Logistics Services (GLS) Missions	8	Orbit supply
NASA Artemis Base Camp Foundation Habitat	1	Surface habitat
NASA Artemis Base Camp Mobility Habitat	1	Surface habitat
NASA Artemis Base Camp Logistics Mission	2	Surface logistics
NASA Lunar Terrain Vehicle	1	Surface rover
NASA Lunar Trailblazer (SIMPLEx 5)	1	Orbit–mapping
NASA Lunar Vertex Rover 1 (on a CLPS platform)	1	Surface lander/rover
NASA CLPS Missions (multiple spacecraft from different organizations)	26	Science and Technology
Air Force Research Laboratory (AFRL) Defense Deep Space Sentinel	1	Surveillance demonstrator
AFRL Oracle	1	Mobility, detection, and tracking
Defense Innovation Unit Nuclear Propulsion Demonstrations	2	Nuclear propulsion/power
DARPA Demonstration Rocket for Agile Cislunar Operations (DRACO)	1	Nuclear thermal rocket
LunaNet/NASA	2	Lunar network capability
Argo Space Corp	1	Space transfer vehicles
AstroForge	1	Asteroid mining
Astrolab	1	Planetary surface rovers
Blue Origin	4	Surface landers
Crescent Space	1	Communications satellites
Firefly Aerospace	8	Landers
Interlune	1	Lunar resource harvesting
Lonestar Data Holdings	1	Off-planet data storage concepts
Lunar Outpost	4	Rovers
Quantum Space	10	Orbital data platform infrastructure
SpaceX Cislunar Tourist Mission	1	Orbit around the Moon

USG MISSIONS

COMMERCIAL MISSIONS

Table 3: Uncrewed International Cislunar Missions 2024–2033

Country	Number	Mission Types
Australia	1	Rover
Canada	2	Canadarm3 (Gateway), rovers
China	6	Orbiters, relay satellites, rovers, hoppers
Europe (ESA)	4	Flyby, orbiter, relay satellite, lander
Europe/Japan	1	CubeSat
India	1	Lander/rover
Italy	1	Instrumentation for precision landing
Japan	3	Flyby, rovers
Pakistan	1	Flyby/lander
Russia	4	Orbiters, landers, rovers
South Korea	2	Lander and rover
Thailand	1	Orbiter
Türkiye	2	Landers
United Arab Emirates	2	Rovers
Canada	2	Orbiting CubeSats
Germany	2	Landers
Germany/Israel	3	Landers
Israel	1	Orbiter, landers
Japan	3	Lander
Mexico	1	Multiple microrobot explorers

GOVERNMENT MISSIONS (Australia through United Arab Emirates) | NON-GOVERNMENTAL MISSIONS (Canada through Mexico, second group)

Lagrange Missions Are Also Being Planned

In addition to the cislunar missions listed in Table 2 and Table 3, a total of 20 uncrewed missions to Lagrange points are planned during this time frame. Ten are to be executed by the USG (NASA and the National Oceanographic and Atmospheric Administration), one by a U.S. nongovernmental organization, and nine to be carried out by ESA, China, Japan, and Russia.

The interest in cislunar space is highlighted through both the growing number of announced or planned missions and the number of countries and companies engaged. How this phase of our exploration of the solar system unfolds will be determined by the enthusiasm of the governments providing the funding and the business cases that can be made to spur commercial involvement.

To the Moon! Crewed Lunar Missions

The U.S.-crewed return to the Moon was energized in December 2017 with the national Space Policy Directive-1, "Reinvigorating America's Human Space Exploration Program."[33] The stakes were raised in March 2019 with the announcement from the White House National Space Council that NASA would send "the first woman and the next man" to the Moon by 2024 through the execution of the Artemis campaign.[34]

Meanwhile, China has been systematically pursuing their lunar exploration aspirations first with a series of uncrewed lunar landings and placement of communications elements in cislunar space in support of their planned lunar landing and research station development.[35] India is also developing its own human spaceflight program with goals of putting an Indian space station in Earth orbit by the mid-2030s and landing humans on the Moon by 2040.

NASA-led Artemis Campaign. The NASA Artemis campaign comprises six major programs to develop the systems required to put U.S. astronauts back on the Moon with the ultimate goal of establishing a long-term human presence on the lunar surface for science and technology development. Systems include the Space Launch System, the Orion crew vehicle, ground systems to support both USG and commercial launches, the Gateway lunar space station, Human (lunar) Landing System (HLS), and the surface exploration vehicle system. Figure 4 shows several the Artemis campaign systems.

Having successfully completed the Artemis I mission in late 2022, NASA continues preparations for the 2025 Artemis II mission, which will fly humans around the Moon. Artemis III, planned for late 2026, will be the first time the United States has landed astronauts on the Moon since 1972. Artemis IV–VI missions are planned through 2031 and will include the on-orbit assembly of the Gateway space station.

Figure 4. Clockwise from left, the space launch system (SLS) launching Artemis I mission, HLS design concepts from SpaceX and Blue Origin, the Orion Spacecraft, and the Axiom Extravehicular Mobility Unit (AxEMU). *(Source: NASA)*

The Artemis campaign has not been without challenges. The mission architecture is complex, eventually requiring multiple launches on multiple launch vehicles (SLS, Starship, and Falcon Heavy), including three separate crewed spacecraft (Orion, Gateway, and HLS). Exacerbating the situation is the fact that each of the system elements is managed as a separate program with no overarching systems engineering function defined (hence the use of the term "campaign" rather than "program"). The Artemis I mission revealed critical issues with the Orion heat shield, separation bolts, and power distribution system. These anomalies pose a danger to the crew and must be addressed before the next flight.[36] NASA continues to struggle with schedule slips and cost overruns, as has been widely covered by the media. The NASA Inspector General stated that Artemis costs could reach $93 billion between 2012 and 2025, not including $42 billion for formulation and development costs. It is estimated that the first four Artemis missions will incur $4.2 billion each in production and operating costs for the SLS and Orion.[37]

A major strength of the campaign is the international interest and participation that has resulted from the Artemis Accords, first announced by the U.S. Department of State and NASA in May 2020. The eight founding members of the Accords are Australia, Canada, Italy, Japan, Luxembourg, the United Arab Emirates, the United Kingdom, and the United States. Now signed by 45 countries as of October 13, 2024 (see Figure 5),[38] the Accords are a set of principles and norms of behavior for operating safely and cooperatively on the Moon in the name of scientific and commercial activities. They are separate from the Artemis campaign, which involves bilateral science and technology cooperative agreements with the United

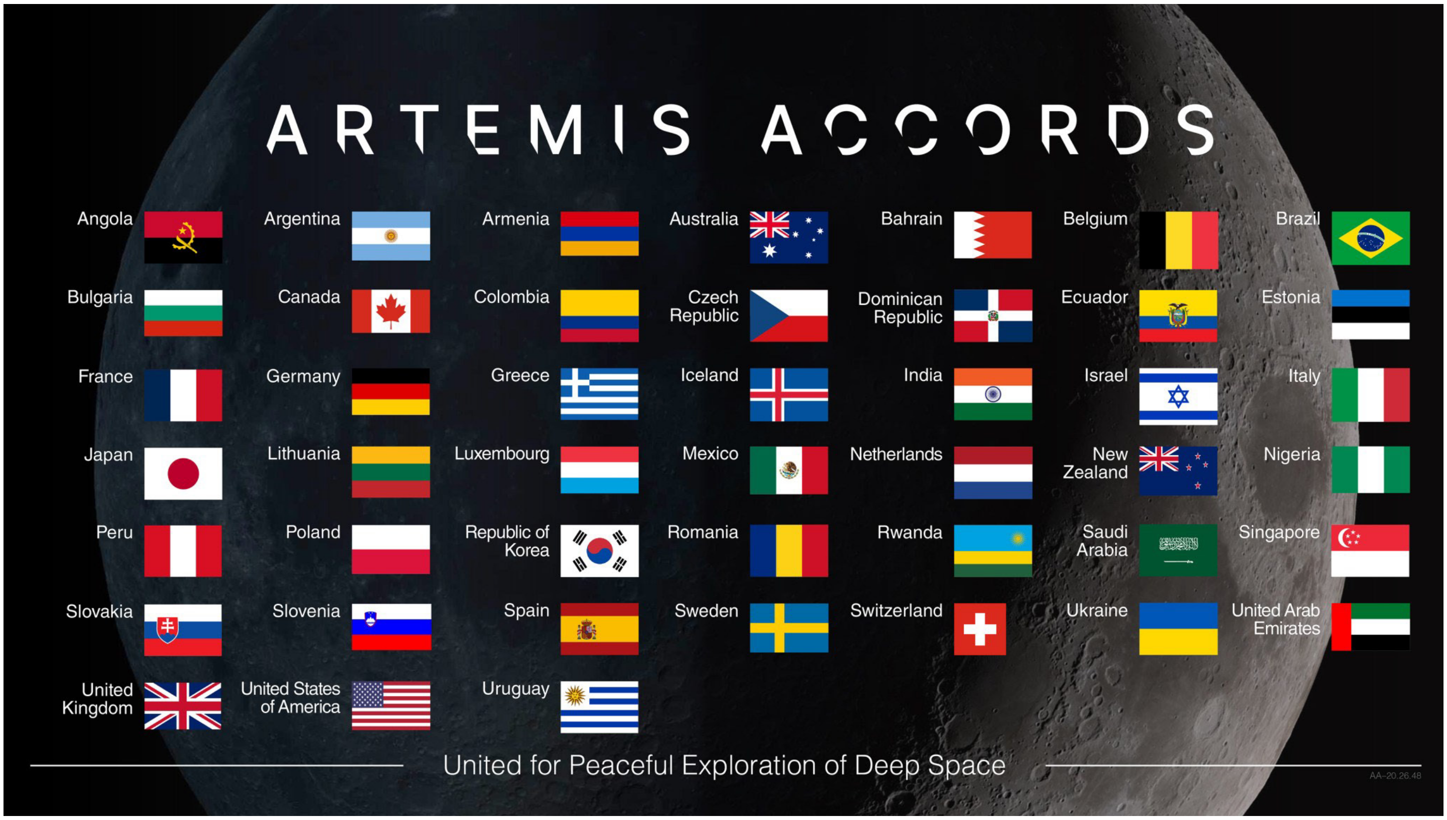


***Figure 5. Signatories to the Artemis Accords as of October 13, 2024**. (Source: NASA)*

States. With so many international and private sector players planning to conduct missions and operations in the cislunar region, the Accords aim to establish a nonbinding common set of principles grounded in the Outer Space Treaty to govern those activities.

International Lunar Research Station (China). China is also progressing on plans to establish a place in cislunar space. The ILRS will be developed over the next decade and consists of five development phases. This long-term research station at the lunar south pole was proposed by China initially, with Russia as a partner, in 2021. China hopes to partner with as many as 50 other countries to develop the ILRS.[39] Current partners include 13 countries and nearly 30 international research institutions (see Table 4). Similar to NASA's plans, their goal is to develop a comprehensive scalable science research facility for multidisciplinary large-scale technical and scientific research activities including exploration, resource development, and technology verification. The intention is for the ILRS to operate autonomously on the lunar surface using assets in lunar orbit with short-term crew participation.

Table 4: International Lunar Research Station Signatories (as of October 2024)

China	Russia
Azerbaijan	Senegal
Belarus	Serbia
Egypt	South Africa
Kazakhstan	Thailand
Nicaragua	Venezuela
Pakistan	

The Chang'e series of missions has already laid the foundation for developing the technologies needed to land humans on the Moon. For example, the recent Chang'e-6 far-side sample return mission included a complex lunar orbit and rendezvous maneuver, which was not necessary for the sample return mission, but an important steppingstone to transporting humans safely to and from the lunar surface.[40]

China's Queqiao-1 communications relay orbiter was deployed in 2018 to a halo orbit around L2 and the Queqiao-2 relay satellite was deployed in 2024 in a highly elliptical orbit around the Moon.[41] The Queqiao-2 mission included deployment of two experimental Tiandu CubeSats to verify important communications technologies supporting a full range of Chinese cislunar missions.

Chang'e-7, planned for 2026, will include a lander and an orbiter and use the Queqiao-2 relay for communications to execute a detailed investigation of the environment and resources at the lunar south pole, similar to what the nearly completed, but now canceled, NASA Volatiles Investigating Polar Exploration Rover (VIPER) mission would have done.[42] Chang'e-8 (2028) will include a lander, a hopper (leaping robot), a rover, and a lunar operations robot to test technologies for in-situ resource utilization.

Gaganyaan Missions (India). Building on the successes of the three Chandrayaan lunar robotic exploration missions and the Aditya L1 mission, the Indian Space Research Organization (ISRO) initiated a crewed spaceflight program in November 2022.[43] Known as Gaganyaan (celestial vehicle), the ISRO program aims to develop a human-rated launch vehicle and a crewed orbital vehicle, including service module, and has initiated crew training at the Astronaut Training Facility in Bengaluru. In addition to the Bharatiya Antariksha Station planned for LEO by 2035,[44] India also plans a human lunar landing by 2040. Quoting from the prime minister's press release, "To realize this vision, the Department of Space will develop a roadmap for Moon exploration. This will encompass a series of Chandrayaan missions, the development of a Next Generation Launch

Chandrayaan-3

The Indian Chandrayaan-3 mission achieved humanity's first successful soft landing of a spacecraft in the region of the lunar south pole, making India the fourth country to soft land on the Moon after the USSR, the United States, and China.

Vehicle (NGLV), construction of a new launch pad, setting up human-centric laboratories and associated technologies." The program is still evolving.

Observations and Recommendations

Observation 1 – Exploration and Lunar Outposts. The strategic importance of cislunar space to exploration, science, and research goes beyond the coveted lunar south pole region. The first nation or coalition of nations to successfully establish long-term lunar surface operations could potentially have an advantage and, by virtue of their presence, discourage other nations from using a particular area. While the United Nations' Outer Space Treaty[45] precludes claiming sovereignty over a particular area, it does not address how to resolve issues that might arise between two entities using the same or nearly the same location. For example, how might one actor's launch and landing activities affect mining equipment or human safety of another actor?

Media reports indicate that China is on track to reach its goal of landing humans on the Moon by 2030. While nominal Artemis milestones are scheduled to happen well before 2030, early delays, heat shield issues, and governmental analysis have already delayed Artemis II to late 2025, possibly 2027.[46, 47]

Recommendation 1. The United States should continue to invest in lunar exploration and exploitation through the NASA Artemis campaigns, CLPS Program, and national security space missions (e.g., AFRL Oracle) aimed at establishing foundational interoperable cislunar infrastructure commensurate with Objective 4 in the NCSTS for a strong U.S. presence in cislunar space; this includes supporting civil and commercial lunar surface operations. Investments should be at a level to ensure mission success while seeking cost-effective solutions, to include partnering with other nations and private space companies.

Recommendation 1 – Supplemental. It is essential that a public relations and public education campaign be mounted to help ensure continued funding for Artemis and other vital USG activities in cislunar space.

Observation 2 – Situational Awareness. Some experts argue that China is moving ahead of the United States in light of recent successes of the four Chang'e lunar landing missions versus only one partial success of the four recent U.S. commercial and international partners' landing mission attempts.[48, 49] China is also operating a communications relay satellite at L2 and has twice landed spacecraft on the far side of the Moon. The United States and its partners cannot observe these operations—be they scientific or military—because the only capable U.S. asset, the Lunar Reconnaissance Orbiter, has very limited viewing opportunities due to orbital mechanics.

Recommendation 2. The United States must establish and then enhance its situational awareness capabilities in cislunar space. Observation and tracking capabilities are key infrastructure components to maintaining safe operations and security in this strategically important region. These capabilities are also crucial for successful lunar orbital and surface missions. The AFRL initiatives (e.g., Oracle) are a good start.

Observation 3 – Governance. It is clear that the United States will be one of a number of international players in the cislunar mission space. How those players from different nations, regional agencies, and governmental or commercial entities govern themselves is still evolving. The partnerships forming around the Artemis campaign and the ILRS represent different camps. In comparison to the Accords, there is also the ILRS Guide for Partnership developed by China.[50] The guide aims to define the research station, describe the scientific areas of interest, and establish a framework for cooperation and opportunities for collaboration in ILRS activities. While it does not appear that these two sets of guidelines are in conflict, there may still be misperceptions or tensions that arise from current geopolitics. How the Artemis and ILRS partners interact with each other to deconflict cislunar activities and prevent interference remains an open question.

In addition to agreements already in process, there is also concern for operational norms of behavior and increased cislunar space debris, which could include ejecta from lunar launches and landings, and other hazards as discussed in the Bulletin of the Atomic Scientists (January 2022).[25] A recent study posits that many aspects of operating in the cislunar regime are not compatible with the current space debris mitigation guidelines and requirements.[51] Collisions or explosions in low lunar orbit would endanger humans on the lunar surface with no atmosphere to slow down debris. And because orbital trajectories are not always predictable in the cislunar region, tracking objects becomes a challenge, meaning collision avoidance warnings are not reliable, particularly for debris or retired spacecraft, at least for the foreseeable future.

Recommendation 3. The United States must take a leadership role in establishing and contributing to governance agreements and international norms of behavior to promote sustainable science, exploration, and resource utilization and to protect personnel working in cislunar space. More important is that we work to ensure that key regions of cislunar space do not become unusable as a result of space debris or haphazard resource exploitation that might either restrict or prevent the use of certain areas of the Moon, like the lunar south pole.

Conclusion

Through providing a physical description of cislunar space, describing reasons behind increased interest in this region, and summarizing planned lunar missions, both crewed and uncrewed, this chapter has presented the current cislunar state of play. The analysis presented in the observations informs the three recommendations that have been provided. As long as the United States maintains its enthusiasm and motivation to push cislunar development forward on the civil, commercial, and security fronts, it has the possibility of maintaining a place of leadership in space. If there is a path to cooperation, or at least a healthier "coopetition," the United States should take the initiative to lead humanity in that direction.

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