

FEBRUARY 2022



FLY ME TO THE MOON

Worldwide Cislunar and Lunar Missions



AUTHOR

Kaitlyn Johnson

A Report of the
CSIS AEROSPACE SECURITY PROJECT

CSIS | CENTER FOR STRATEGIC &
INTERNATIONAL STUDIES

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▾ Project Scope

This project contains a compendium of cislunar and lunar missions from government and commercial entities around the world. There are several planned national and commercial missions to explore cislunar space or the Moon. Often government efforts will enable or utilize private industry missions; however, sometimes commercial space companies are independently pursuing such missions. This paper concludes with analysis on the trends and commonalities across all of these planned endeavors.

Timelines for space missions shift regularly due to challenges such as funding inequities or technical delays. While this paper is as accurate as possible as of its publication, it is highly likely that dates and details of missions will continue to change as missions progress.

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Contents

Introduction	1
Defining Cislunar	2
Europe and Russia	3
<i>European Space Agency</i>	4
<i>France</i>	5
<i>Germany</i>	5
<i>Italy</i>	5
<i>Luxembourg</i>	6
<i>Russia</i>	6
<i>Ukraine</i>	8
<i>United Kingdom</i>	8
Indo-Pacific	9
<i>Australia</i>	10
<i>China</i>	10
<i>India</i>	12
<i>Japan</i>	12
<i>South Korea</i>	13
<i>Thailand</i>	13
Americas	15
<i>Canada</i>	16
<i>Mexico</i>	16
<i>United States of America</i>	16
Middle East and Africa	21
<i>Israel</i>	22
<i>Turkey</i>	22
<i>United Arab Emirates</i>	22
Trends across Planned Missions	23
About the Author	28
Endnotes	29

Introduction

The crowning achievement of the notorious Space Race between the United States and the Soviet Union occurred in July 1969, when the first humans landed on the Moon. Prior to this, the United States and the Soviet Union sent several uncrewed missions to the lunar surface, culminating in an American crewed mission on the Moon. Now, over 50 years later, nations are looking toward the Moon as a goalpost of both national space capability and pride. To achieve these goals—and potentially go beyond the Moon to Mars—nations will need to build significant cislunar and lunar infrastructure. This open-source assessment aggregates and analyzes publicly available statements, documents, and sources describing these worldwide efforts in cislunar space.

This assessment begins with an evaluation of national and international definitions of cislunar space, as there is no commonly accepted definition across the international or technical community. It then evaluates national and commercial plans to send missions to cislunar space or the Moon. The analysis presents an overview of national civil, military, and commercial activity, as well as multinational activity, in or planned for cislunar space.¹ Lunar missions are also included to showcase the demand signal of missions that will pass through cislunar space or be supported by satellites in cislunar orbits. The assessment concludes with key trends, possible future flashpoints, and recommendations for further analysis.

Many nations view lunar and cislunar investments as a means to advance their domestic space industrial capabilities and as the first step toward a greater presence in near-Earth space. The scientific and economic potential of a robust space presence and international partnerships in space drives many companies and countries to pursue lunar and cislunar missions.² The opportunities lunar and cislunar missions present have caused nations to begin designing policies to regulate and promote celestial resource extraction and in situ resource utilization (ISRU)—or the production and manufacture of materials found on the Moon or other celestial bodies.

The rush to settle cislunar space or the Moon is motivated both by science and the important strategic value held by certain sites in cislunar space or on the lunar surface. For various sites, certain physical properties add value, such as stability on orbit or the prospect of water in the form of ice. For more detail on these high-value locations, see: *Eyes on the Prize: The Strategic Implications of Cislunar Space and the Moon*.³

Thus far, there is no consensus on the demarcation of cislunar space.



Defining Cislunar

Despite many nations, organizations, and companies investing in lunar and cislunar ventures, few specifically define *cislunar*. Competing definitions include:

- “The area between the Earth and the Moon, including the Moon’s orbit”—including low Earth orbit (LEO), medium Earth orbit (MEO), and geosynchronous orbit (GEO);⁴ and
- The distance from beyond GEO (also known as XGEO) to the Moon’s surface.⁵

The definition of cislunar may influence national policies and plans, commercial investments, and broader international understanding. Thus far, there is no consensus on the demarcation of cislunar space, and to ensure entities with lunar ambitions are not talking past one another, establishing a formal definition of cislunar space could be a valuable action taken by the United Nations. While China, Russia, and the United States occasionally reference the bounds of cislunar space in public documents or statements, other nations do not appear to specifically and consistently define cislunar space. While it seems that many civil space organizations and universities have written on the technical aspects of cislunar space, policymakers and the wider international community have not settled on one consistent technical definition. This may be because there is no clear “shoreline” or distance from Earth at which the properties of the space environment change significantly to designate it as cislunar space.

For this paper, cislunar space includes the area between XGEO and the Moon, as well as orbits that are affected by lunar gravitational pull and go beyond the Moon. This does not include LEO, MEO, and GEO but does include low lunar orbit (LLO)—the area between 100 kilometers of the Moon’s surface and the L1 and L2 Lagrange points.⁶ Earth-Moon Lagrange points L4 and L5—the stable regions of the Moon’s Trojan points along the Moon’s orbit—are also

considered part of cislunar space for the purposes of this paper. Once satellites are placed in XGEO orbit, or higher, the Moon’s gravity has an increasingly significant effect (in addition to the Earth’s gravity). At lower altitudes (including LEO, MEO, and GEO), the Moon’s gravity has relatively less effect on satellites due to the nonuniformity of the Earth’s gravitational field and other forces, such as atmospheric drag at lower altitudes.⁷ This definition of cislunar space also appears to be most consistent with much of the technical research found.

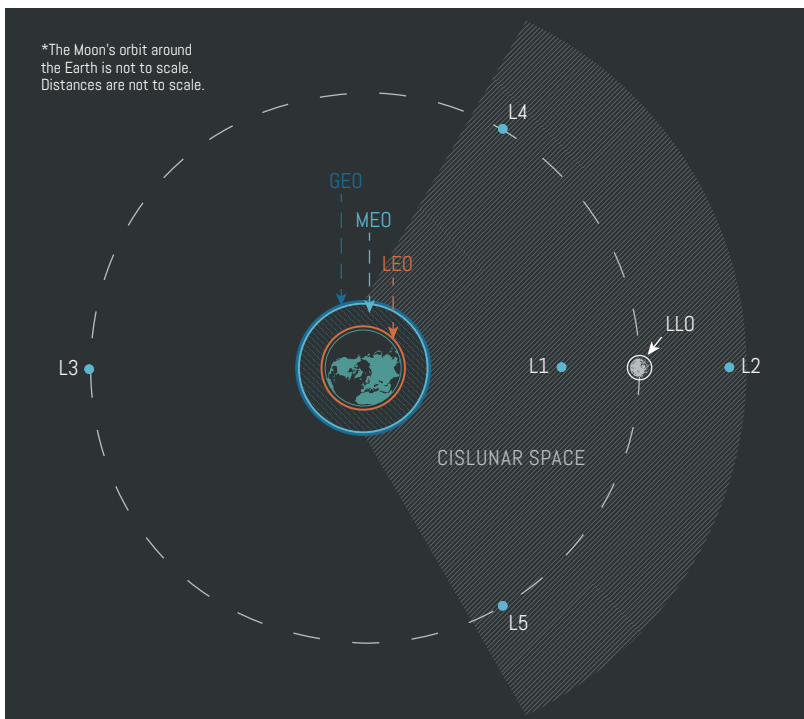


Figure 1: Visual Representation of Cislunar Space

Source: Author's own research and analysis.



EUROPE & RUSSIA

European Space Agency

The European Space Agency (ESA) is contributing to many international cislunar and lunar efforts. One prominent effort is the partnership between ESA and Roscosmos, the Russian space agency, on three lunar missions involving two landers and one orbiter. For Luna 25, ESA provided a European Pilot-D camera that will assist the lunar landing by imaging the terrain. Luna 25 is expected to launch in July 2022.⁸ Expected in 2024, the Luna 26 orbiter mission will utilize an ESA ground station for communications back to Earth.⁹ In 2025, the Luna 27 mission will launch and land on the Moon. ESA is contributing to the Luna 27 mission once again by providing Pilot cameras that will assist the lander in completing the challenging landing near the Moon's south pole. The Pilot cameras observe the lunar terrain and correlate their view with data from maps of the lunar surface. This allows the lander to recognize craters and determine its location over the Moon's surface while landing. For Luna 27, ESA will also provide the European Prospect Drill, which will collect samples of water, ice, and other minerals and chemicals under the lunar surface at the south pole. Along with Russian instruments, the European drill will assist in the lander's mission to identify water and other minerals by using an onboard miniature laboratory built into the drill itself.¹⁰

As part of ESA's Space 4.0 initiative, which highlights new commercial technologies as well as new national objectives in space, ESA proposed the Moon Village concept.¹¹ The Moon Village is an idea that a cohesive lunar community can be "created when groups join forces without first sorting out every detail, instead simply coming together with a view to sharing interests and capabilities."¹² The Moon Village would allow participation from any nation or non-governmental actor, and participation would vary in involvement, sector, and activity. For example, some actors would have a wholly robotic presence, while some might wish to establish a permanent crewed scientific outpost (such as in Antarctica), while others may only be interested in tourism to the Moon. The Moon Village is an idea or vision for future human cooperation not defined by national interest or competition.¹³ However, any of these future activities envisioned would require significant cislunar and lunar-based infrastructure, such as cislunar communications relays and lunar life support.

On April 1, 2021, the new director of ESA met the director of the China National Space Administration (CNSA) to discuss future space cooperation between the two space agencies. According to the CNSA press release,

the discussion focused around lunar and deep-space exploration missions, as well as telemetry, tracking, and control for these missions.¹⁴ In the past, ESA and CNSA have discussed cooperation for south pole lunar missions, including the successful Chang'e-5 lunar return mission.¹⁵

ESA's Moonlight Initiative

The Moonlight Initiative is an effort led by ESA to partner with spacefaring nations and commercial space companies to develop a communication and navigation infrastructure in cislunar space. This network will support lunar missions and add the capability for lunar landers to land on the lunar surface more easily because they could rely on a shared the network instead of developing separate communications and navigation systems for individual missions.¹⁶

An impressive collection of European companies, organizations, and universities will support the effort, including Surrey Satellite Technology, Airbus, SES, Kongsberg Satellite Services, Goonhilly Earth Station, and GMV-NSL.¹⁷

A second tranche of European commercial companies will also take part in the initiative, including Telespazio, Thales Alenia Space, Inmarsat, Hispasat, Aerospace Logistics Technology Engineering Company, Argotec, and Nanoracks Europe, as well as two universities: the Politecnico Milano and the Università Commerciale Luigi Bocconi. In addition to this wide base of commercial expertise, ESA plans to engage with other spacefaring nations, including China, India, Russia, and the United States.¹⁸

ESA Support to the U.S. Lunar Gateway and Artemis Programs

ESA selected Airbus Defence and Space as the main contractor for the European Service Module (ESM) of the Artemis program, run by the United States' National Aeronautical and Space Administration (NASA). While NASA's Orion spacecraft will carry crew from Earth to cislunar space, the ESM will act as the spacecraft's service module and will be providing "electricity, water, oxygen, and nitrogen, as well as keeping the spacecraft at the right temperature and on course."¹⁹ A total of six ESMs have been awarded to Airbus as of October 2021.²⁰ Three ESMs are currently in development to support the Artemis program. ESM-1 is already paired with the U.S.-designed Crew Module and is undergoing final preparations prior to a planned 2022 test launch.²¹ ESM-2 is ready to be flown from Germany to NASA's Kennedy Space Center and will be included

in the first crewed test flight to send astronauts in orbit around the Moon.²² ESM-3 will support the landing of the first woman and person of color on the Moon.

ESA's European Large Logistics Lander (L3) program is currently in the study phase with two potential prime contractors, Airbus Defense and Space and Thales Alenia Space.²³ These two companies will study options for the Cis-Lunar Transfer Vehicle (CLTV) for ESA. The CLTV will be an advanced on-orbit servicing satellite that can also assist in lunar descent. The CLTV will be able to transport cargo or fuel into lunar orbit and transfer a larger lunar module into LLO for landing and ascent missions. It will also be capable of servicing other satellites in non-cislunar orbits, such as GEO.²⁴ The planned lander is envisioned to support the Artemis program and independent European missions by delivering massive amounts (possibly 1.5 tons) of cargo payload to the lunar surface.²⁵ The study phase began in mid-2021 and is expected to move to the System Design Review in late 2022.²⁶ ESA has already selected three contending payloads for the first L3 mission. The first payload will be selected in 2022 with an undefined first launch date in the late 2020s.²⁷

The international habitation module, or I-HAB, is being led by ESA, in cooperation with the Japan Aerospace Exploration Agency, Canadian Space Agency, and NASA. The I-HAB is a pressurized module designed for crew quarters that will allow for external vehicle docking. Thales Alenia Space is the prime project manager and is working to develop aspects of the pressurized module infrastructure, including avionics, thermal and mechanical systems, and pressurized hatches.²⁸ The I-HAB is intended to launch in 2026.²⁹

France

The French space agency, Center National D'Études Spatiales (CNES), does not currently have any planned independent cislunar or lunar missions, but it plans to partner bilaterally with many other nations and through ESA. For example, France was one of the first partners that signed on to NASA's Artemis program. Additionally, the Chinese Chang'e-6 mission will feature a French radon measurement instrument, DORN.³⁰ DORN's objective is to measure and record regolith outgassing and other volatile gasses in the lunar exosphere. Chang'e-6 is expected to launch in 2024.³¹

France is not currently planning any military or national security space missions to cislunar orbit or the lunar surface.³² There are also no concrete plans from French commercial space companies to conduct cislunar missions without government funding or as part of a broader ESA initiative. However, a French-Italian company, Thales Alenia Space, has been awarded several contracts to support ESA's contribution to the Artemis program. See the Italy section for details on these programs.

Germany

Germany is not currently planning any military or national security space missions to cislunar orbit or the lunar surface.³³ The German Space Agency (DLR) is also not planning any national civil space missions to cislunar space. While most of Germany's civil space endeavors are through ESA, DLR funded an effort from Kiel University to develop an instrument that measures radiation in space. This effort, known as the Lunar Lander Neutron and Dosimetry instrument, was successfully launched onboard China's Chang'e-4 lunar lander, which is still active.³⁴

Plus Ultra Space, a European space company based in Germany, Spain, and Luxembourg, plans to build a constellation of satellites called Harmony in LLO to establish better communications and navigation infrastructure for cislunar and lunar missions.³⁵ Plus Ultra Space recently signed a memorandum of understanding (MOU) for a demonstration mission in 2023, with the satellite becoming operational in LLO by 2024.³⁶

Italy

The Italian Space Agency is waiting for its nanosatellite ArgoMoon to launch on NASA's Space Launch System (SLS). Designed by Italian company Argotec, the ArgoMoon satellite is critical to testing technology and providing proof of concept for future cislunar missions. A key aspect of the mission is to "demonstrate the ability to perform operations in close proximity of the Interim Cryogenic Propulsion Stage (ICPS)" on the Orion spacecraft.³⁷ The ICPS is the second stage liquid oxygen/liquid hydrogen-based booster.³⁸ ArgoMoon will take pictures of the ICPS during its flight to the Moon.³⁹ After this test, ArgoMoon will photograph the Earth, Moon, and surrounding environment in an orbit that passes through

cislunar space.⁴⁰ The expected launch date continues to slip with SLS delays but is currently expected in 2022.⁴¹

As previously mentioned, the French-Italian space company Thales Alenia Space is a key partner for Artemis and the Lunar Gateway. Italy may further support the Artemis program by supplying “crew habitats, lunar surface scientific investigations, and telecommunications services”; however, further details have not yet been announced.⁴²

ESA awarded Thales Alenia Space several cislunar and lunar contracts to support these international partnerships. The Habitation and Logistics Outpost (HALO)—the first module for the Lunar Gateway—is also being supported by Thales Alenia Space. HALO is led by U.S. company Northrop Grumman Corporation, and Thales Alenia Space was selected to “provide its primary structure and micrometeoroid protection system.”⁴³ HALO is planned to launch in 2024, along with the Power and Propulsion Element and will serve as the pressurized living quarters for any visiting astronauts to the Lunar Gateway.⁴⁴

ESA also awarded Thales Alenia Space the European System Providing Refueling, Infrastructure, and Telecommunications (ESPRIT) contract in early January 2021.⁴⁵ The ESPRIT module for the Lunar Gateway is a cross-Thales Alenia Space mission involving teams from France, Italy, Belgium, Spain, and the United Kingdom. ESPRIT will be responsible for communications and refueling for the Lunar Gateway and will have an observation window. ESPRIT refueling will extend Lunar Gateway’s operational life, as well as enable a future reusable lunar lander or support other deep-space exploration missions.⁴⁶ There are two modules that make up ESPRIT: the HALO Lunar Communication System that is planned to launch in 2024 and the ESPRIT Refueling Module that is planned for launch in 2027.⁴⁷

▾ Luxembourg

While not a major space power, Luxembourg has positioned itself to have a niche in space resourcing and mining, including materials on the Moon. To do this, the country launched the SpaceResources.Lu Initiative in 2016, which established a “unique legal, regulatory, and business environment enabling private investors and companies to explore and use space resources.”⁴⁸ Luxembourg’s legal and regulatory framework allows legal ownership of minerals or other resources mined

from within celestial bodies. While the 1967 Outer Space Treaty dictates that no territory can be claimed on the Moon or another celestial body, Luxembourg asserts that there is nothing illegal about claiming resources derived from a celestial body.⁴⁹ An analogy often referred to is the finishing industry: while a nation cannot own international waters, fishermen have ownership rights to the resources (e.g., fish, shellfish) they catch in them.⁵⁰

Commercial

This legal framework in Luxembourg has drawn several commercial endeavors, such as Cislunar Industries and ispace Europe, to establish headquarters in Luxembourg. Luxembourg is a part of the Artemis program and intends to support in situ resourcing and mining missions.⁵¹

▾ Russia

The Russian space agency, Roscosmos, has several partnerships and cooperative lunar missions. Furthermore, there are several pseudo-commercial subsidiaries of Roscosmos that will likely be involved in these future government-led lunar missions. The flagship of Russian lunar exploration is the Luna program, which includes five planned missions: Luna 25–29 (Table 1 includes a description of each mission).

▴▴▴

Luxembourg has positioned itself to have a niche in space resourcing and mining, including materials on the Moon.

▴▴▴

Government

Luna 25 is a lunar lander mission and will be the first Russian lunar program since Luna 24 in 1976.⁵² Luna 25 will land near the Moon’s south pole to search for signs of water and other minerals under the lunar surface as well as to evaluate dust and plasma that make up the Moon’s exosphere. The mission is expected to last at least one year and will launch in May 2022, a date later than originally expected due to critical issues that arose during testing.⁵³ As aforementioned, ESA is a key partner for this mission.

Scheduled for 2025, the Luna 26 orbital mission will study the lunar surface from low lunar polar orbit to inform the landing site for Luna 27 and serve as a communications relay for Russian lunar landers.⁵⁴ Luna 26 will also “monitor the solar wind and high-energy cosmic rays.”⁵⁵ ESA is again partnering with Roscosmos on this mission.

Luna 27, or Luna Resurs, is anticipated in 2026 and will not only land on the Moon but also be able to prospect and analyze the lunar surface. The highly capable drill that is central to the mission is being developed by ESA and will search for underground ice and study the makeup of the lunar bedrock.⁵⁶ This mission will bring better understanding of how much subsurface ice might be present near the south pole of the Moon and how accessible this

water might be as a resource for future lunar missions, including a sustained presence on the Moon.

Luna 28, or Luna Grunt, is a lunar sample return mission planned by Roscosmos. The Luna 28 module is expected to return to Earth samples of regolith from the lunar south polar region. The expected total mass of these samples is 2 to 4 kilograms. The mission will select samples from various locations around the south pole that are likely to include ice.⁵⁷ The mission is expected to launch in 2027 or later.⁵⁸ Luna 29 will include a lunar rover that will carry instruments capable of analyzing geological samples on site.⁵⁹ The estimated launch date for this mission is 2029.⁶⁰

Russia is planning for a crewed mission to orbit the Moon in 2028 called Oryol.⁶¹ Dependent on successful uncrewed flights in 2023 and 2024, the Oryol spacecraft will fly around the Moon and better position Russia for consistent crewed capability to cislunar space and—with a future lunar lander—to the lunar surface.⁶² Recently, Dmitry Rogozin, director general of Roscosmos, announced that he met with NASA representatives at the October 2021 International Astronautical Congress to discuss the possibility of the Oryol spacecraft with the Lunar Gateway and the need to adapt technical standards to ensure compatibility.⁶³

Table 1: Announced Russian Cislunar and Lunar Missions
Source: Author’s own research and analysis.

NAME	ESTIMATED LAUNCH	LOCATION	MISSION	PARTNERS
Luna 25	May 2022	Lunar South Pole Region	Search for water and minerals under lunar surface and evaluate exosphere	ESA
Luna 26	2025	Low Lunar Orbit	Study lunar surface and determine Luna 27 landing site	ESA
Luna 27 (Luna Resurs)	2026	Lunar South Pole Region	Prospect and analyze below lunar surface	ESA
Luna 28 (Luna Grunt)	2027 or later	Lunar South Pole Region	Collect samples (including ice) and return to Earth	N/A
Luna 29	2029	TBA	Rover with capability to analyze lunar geological samples	N/A
Oryol (test)	2023	Cislunar Orbit	Uncrewed test flight	N/A
Oryol (second test)	2024	International Space Station	Test flight	N/A
Oryol	2028	Crewed Lunar Mission	Crewed lunar landing	N/A

In November 2021, Rogozin directed the Energia Space Rocket Corporation to study the possibility of downsizing the Oryol spacecraft to make a smaller two-seater resupply spacecraft. Dubbed Orlyonok, this craft would use 90 percent of Oryol's technology and therefore be a cheaper alternative.⁶⁴

Another long-term goal for Russia is to establish a human settlement on the Moon by 2040. There are several stages to achieving this goal, including landing Russia's first cosmonauts on the Moon.⁶⁵ One recent announcement is the Russian-Chinese agreement to establish a joint lunar base (see page 11 for more).⁶⁶ Russia is clearly investing in cislunar and lunar operations for the future of the civil space program; however, it is less clear how the Russian military may utilize this area of space, as there are no public sources indicating plans or goals for lunar military operations.

Another long-term goal for Russia is to establish a human settlement on the Moon by 2040.

Ukraine

Ukraine has no government capability (civil or commercial) to place a satellite in cislunar orbit or on the Moon. However, the Ukrainian government is funding Spacebit, a British company led by a Ukrainian CEO, to place a walking rover on the Moon, possibly in late 2022. The estimated cost to the Ukrainian government is \$1.5 million.⁶⁷

United Kingdom

The United Kingdom is not currently planning any military or national security space missions to cislunar orbit or the lunar surface. The United Kingdom is also not planning any national civil space missions to cislunar space, as most of the United Kingdom's civil space endeavors are through ESA.⁶⁸

Commercial

Spacebit, a UK-based company, is planning two lunar missions. The first will be launched on the inaugural United Launch Alliance (ULA) Vulcan Centaur launch in 2022.⁶⁹ The Spacebit walking rover will be deposited on the lunar surface by the Peregrine lunar lander, developed by the U.S. company Astrobotic. The first walking rover

will move 10 meters from the lander and provide video and 3D lidar imaging of the lunar surface.⁷⁰ A walking rover has legs instead of the traditional wheels to navigate more easily around the rough and cratered lunar surface. Shortly after this first lunar mission, Spacebit will return to the Moon with a second mission, this time launched on a SpaceX Falcon 9 rocket.⁷¹ The second is a Ukrainian mission, described previously.

Surrey Satellite Technology Ltd (SSTL) will launch its Lunar Pathfinder mission in 2024.⁷² The Lunar Pathfinder 1 is a cislunar relay satellite that will likely be in LLO. It is planned to be the first of a series of more capable lunar communication and navigation satellites that will support future lunar (crewed and uncrewed) missions. Lunar Pathfinder 1 will enable easier communication for polar and far-side lunar explorations. Pathfinder will also host two ESA experiments: one is a test of navigation technology for the Moon, and the second is a radiation detection monitor for cislunar space. NASA will also collaborate by providing a laser retro-reflector payload, which will provide data to allow comparison of orbit positioning data from ESA's navigation experiment.⁷³

The Moon Probe Initial Explorer (MoonPIE) project from TCT Aerospace, a UK-based company, intends to launch a lunar sample return mission in 2025. MoonPIE will return around 1 kilogram of lunar samples to Earth for further study. MoonPIE also plans to demonstrate reusability for lunar return missions, as well as send a time capsule to the lunar surface. To reduce ecological harm to the Moon, the mission intends to land only 50 meters from the Apollo 12 landing site.⁷⁴



INDO-PACIFIC

▾ Australia

Australia has a long history of providing integral support to cislunar and lunar missions, including the Australia Carnarvon station that supported the first Moon landing on the Apollo 11 mission.⁷⁵ From its position in the southern hemisphere, Australia is ideally situated to integrate with other telemetry and tracking capabilities from countries in the northern hemisphere.

Government

In coordination with NASA, the recently established Australian Space Agency is promoting a Moon to Mars Initiative. This initiative includes \$150 million for investment in Australian space companies or technologies over the next five years. To distribute funding, the Australian Space Agency has identified three integrated elements for applicants:

- the Supply Chain program, which will focus on developing a noncompetitive (to the United States) supply chain network within Australia;
- the Demonstrator program, which includes grants to promote Australian companies developing space technologies; and
- the flagship Trailblazer program that will contribute flagship Australian space capability within NASA's Artemis program.⁷⁶

On October 12, 2021, NASA and the Australian Space Agency announced plans to cooperate on a future lunar rover. This mission is part of the "Moon to Mars" flagship Trailblazer program and could land on the Moon as early as 2026. Australia will support NASA's Artemis mission by providing a lunar rover that will be able to collect surface samples and return them to an ISRU system, which will attempt to extract oxygen from these samples.⁷⁷

Although Australia recently established a space division within the Royal Australian Air Force, there are no publicly announced plans for military missions to cislunar space.⁷⁸

Commercial

Several commercial Australian cislunar missions are also in progress. Announced in December 2020, Seven Sisters is an Australia-based nongovernmental effort to reach the Moon. A total of 10 entities (including two universities) are collaborating to send Australia's first nanosatellites into cislunar orbit in 2023 to search for accessible water. This effort is in collaboration with NASA's Artemis program, in which the Australian government is a partner.⁷⁹ A stated

Australia has a long history of providing integral support to cislunar and lunar missions.



key goal of the Seven Sisters effort is to firmly establish Australia and Australian industry as leaders in space exploration and research by 2030.⁸⁰

Lunar Ascent, another Australian industry-led effort was announced in December 2020. Lunar Ascent is a satellite transport bus that will provide rideshare opportunities for other government and commercial payloads to cislunar space. The first mission is expected to be around 60 kilograms and launch in 2024. There are two customers committed thus far.⁸¹

Australia-based Saber Astronautics is partnering with Rhea Space Activity, a new U.S.-based space consulting firm that won a \$50,000 contract from the U.S. Air Force to provide lunaspatial intelligence (LUNINT). Saber will work toward creating a 3D dashboard that displays noteworthy objects (including satellites) in cislunar orbit. This product will add to the limited amount of cislunar situational awareness that exists today. If successful, Saber's CEO hopes that the other Five Eyes nations (Canada, New Zealand, the United Kingdom, and the United States) will be interested in similar capabilities.⁸²

▾ China

Like their Russian counterparts, Chinese lunar or cislunar programs are coordinated by the government at one point or another—either through direct investment or indirect ownership of pseudo-commercial companies.

Government - Civil

China's Lunar Exploration Program has conducted several successful civil lunar missions to date. The stated overall scientific goals include to study the water and chemical composition of the Moon, assess the age of the South Pole Aitken basin, evaluate the early impact history of the solar system, perform ISRU tests, and conduct bioscientific experiments, among others. Some of these scientific goals are well underway due to the previous Chang'e missions; however, this section will focus on ongoing or planned cislunar and lunar missions.

Unlike the other countries in this assessment, China is currently operating a robotic lunar rover on the Moon. Chang'e-4 is a lunar lander that conducted the first ever soft landing on the far side of the Moon on January 3, 2019. The Chang'e-4 spacecraft operated in LLO before landing on the lunar surface. The lunar lander released from the spacecraft, Yutu-2, has traversed the lunar surface for over two years, exceeding expectations for its operational life.⁸³

To support the Chang'e-4 mission, China launched two communications relay satellites into cislunar orbit around the L2 point in May 2018. These satellites were designed to support communications from Earth around to the far side of the Moon—a new challenge for humanity, as no other country had ever attempted sustained operations on the far side.⁸⁴

Launched in November 2020, Chang'e-5 is China's first lunar sample return mission. The mission was highly successful and returned 1.731 kilograms of material to the Earth's surface just under a month later. Chang'e-5 included an orbiter and, critically, a lunar lander with the ability to reascend and rendezvous with the orbiter in order to return lunar samples to Earth. The lander included capabilities to drill and scoop materials into a secure capsule, which was later jettisoned from the orbiter and made a hard landing on the Earth's surface.⁸⁵

Chang'e-6 was originally designed as a backup mission, prepared in case Chang'e-5 failed. However, with the success of Chang'e-5, the sixth mission will proceed with a more challenging sample return mission from the lunar south pole on the far side of the Moon. It is intended to launch in 2024. Notably, the Chang'e-6 mission will be equipped with several international payloads, including those from France and Italy. Russia and Sweden have also been identified as potential contributors.⁸⁶

Also anticipated to launch in 2024, the Chang'e-7 mission consists of a cislunar telecommunications relay, a lunar orbiter, a lunar lander, a rover, and a flying probe.⁸⁷ After releasing the lander package (including the rover and probe), the orbiter will continue to make scientific observations and study from cislunar space. After a soft landing on the lunar surface near the south pole, the rover will deploy to perform in situ experiments, while the flying probe will carry an instrument to detect and study water molecules and hydrogen isotopes.⁸⁸ Due to the absence of an atmosphere, the probe will have to be powered by rockets instead of a rotary wing mechanism such as NASA's Mars helicopter, Ingenuity.

With an expected 2027 launch, the details around Chang'e-8 are still solidifying.⁸⁹ A 2020 paper details that Chang'e-8 will include a lunar lander, a rover, and another flying probe to carry out exploration and verification necessary for the future lunar station. This mission will conduct an ISRU experiment to include "separation and extraction of rare gasses from lunar soil."⁹⁰ These experiments are likely to be the foundation of a sustainable Chinese presence on the Moon and will support the future lunar station.

International Lunar Research Station

China has long been planning for a permanent lunar research station, but headlines were made in March 2021 when China and Russia signed an MOU to cooperate on a joint lunar research station. The document is a vague outline of what the partnership may develop into; however, it does outline some goals and principles that will underpin the international effort—specifically, that the International Lunar Research Station (ILRS) will have "the capability of long-term autonomous operation, built on the lunar surface and/or on the lunar orbit that will carry out multidisciplinary and multiobjective scientific research activities, such as the lunar exploration and utilization, lunar-based observation, basic scientific experiment, and technical verification."⁹¹ In a meeting with the ESA director general, the CNSA administrator stated that China and Russia were in agreement to be open to international cooperation from all nations on ILRS. France has already expressed interest in the project.⁹²

An initial version of ILRS is expected to be operational in the early 2030s, with the capability to host long-term autonomous robotic missions and short-term crewed missions. By the late 2030s to early 2040s, ILRS will evolve into a more permanent lunar base that will be able to sustain long-term crewed missions.⁹³

China is well underway to developing the necessary capabilities to establish ILRS, including a new human-rated launch vehicle that will be ready by 2030. This same vehicle will also be able to launch more mass to space than any prior Chinese launch vehicle—something that may be critical to efficiently building the lunar base.⁹⁴ There is also a human-rated lunar lander under development, but there are minimal publicly available details on this project. At a 2020 conference, a presentation indicated that China will also construct a lunar orbiter and crewed rover for future lunar exploration.⁹⁵

Government - Military

There is a scarcity of public information about China's military ambitions in cislunar space and on the Moon. However, in mid-2016, Lieutenant General Zhang Yulin, the deputy chief of the armament development department within China's leading national defense organization—the Central Military Commission—reported that Chinese ambitions included military capabilities in cislunar space. Zhang also described the benefits of using cislunar space and the Moon for research and exploration missions.⁹⁶

India

Lunar exploration is a clear goal of the Indian Space Research Organisation (ISRO). The July 2019 Chandrayaan-2 mission included both a lunar lander and an orbiter. Unfortunately, due to a software glitch, the Vikram lander suffered a hard landing on the lunar surface, which destroyed the lander and rover.⁹⁷ The rover mission was intended to survey the area near the Moon's south pole in search of data on ice below the surface. The orbiter is intended to have a seven-year operational life and is currently in operation in cislunar space.⁹⁸ Chandrayaan-3, a new lunar mission planned for August 2022, includes a lander and rover with the same scientific instruments as the failed Chandrayaan-2 mission. Originally intended for launch in 2021, the mission was delayed due to the Covid-19 pandemic. Chandrayaan-3 will target the same launch site as the Chandrayaan-2 mission.⁹⁹

India is also looking to send humans into space, and if the mission succeeds as planned, India will become the fourth country with a national capability to do so. India's long-term goals appear to include a sustained human presence in LEO, with the potential for further human exploration past LEO, likely to include cislunar space and the Moon.¹⁰⁰

ISRO is also a key partner with Japan on a joint Lunar Polar Exploration (LUPEX) mission, which will launch a lunar lander and rover to the Moon's south pole around 2024.¹⁰¹ For more information, see the Japan section.

Japan

In partnership with ISRO, the Japan Aerospace Exploration Agency (JAXA) is developing the LUPEX mission, which includes a lunar lander and unpressurized rover that will explore the south pole area of the Moon. The mission is expected to launch no earlier than 2024. In October 2020, the JAXA president said that this mission will hopefully lead to further human exploration of the Moon, and that the LUPEX is the first step toward developing a pressurized lunar rover for crewed missions.¹⁰² Furthermore, this mission with ISRO is the foundation for future space cooperation between the two nations, to include “opportunities for cooperation in space situational awareness and [a] professional exchange programme.”¹⁰³ Notable for this cislunar space assessment, the LUPEX mission will not have a communication relay satellite but will directly communicate with ground stations on Earth.¹⁰⁴

Two cubesats, both designed by JAXA and the University of Tokyo, will be launched into cislunar space on an SLS flight in 2022. The EQUULEUS cubesat “plans to demonstrate low-energy trajectory control techniques within the Earth-Moon region at EML2 (Earth-Moon L2 Lagrange point), using a new water propulsion system with low thrust and little propellant.”¹⁰⁵ EQUULEUS will also monitor radiation in near-Earth space by imaging Earth's

China has long been planning for a permanent lunar research station.

plasma sphere. This data should support further research on protecting humans from radiation during extended space travel.¹⁰⁶ The second cubesat, OMOTENASHI (Outstanding Moon Exploration Technologies Demonstrated by Nano Semi-Hard Impactor), will be the smallest lunar lander to date. OMOTENASHI also breaks lunar lander tradition by heading straight to the lunar surface after deploying from the SLS, instead of performing an orbital pass prior to landing. This small and relatively inexpensive satellite could open possibilities for more lunar missions from smaller or emerging space nations.¹⁰⁷

JAXA is also developing the Smart Lander for Investigating Moon (SLIM) lunar lander mission, which will attempt pinpoint landing and obstacle detection capabilities on the lunar surface. This technology will allow future missions to choose a landing site during the mission, instead of having a site prechosen based on easy access or lack of obstacles. According to JAXA, “By achieving this, it will become possible to land on planets even more resource scarce than the moon.”¹⁰⁸ The SLIM mission’s secondary focus is to lighten the weight of the payload and ensure small-scale technology for future missions.¹⁰⁹ This mission is expected to launch in 2022.¹¹⁰ The SLIM payload provides a similar capability as the Pilot camera system that ESA is developing for Russian lunar missions.

In support of the Lunar Gateway, JAXA intends to provide habitation technology and logistics resupply missions.¹¹¹ The logistics resupply missions will be carried out through the H-II Transfer Vehicle (HTV)-X program, which is currently under development to support International Space Station (ISS) resupply missions. The first anticipated launch of the new HTV-X launch vehicle is in 2022.¹¹²

A long-term lunar roadmap presented by Japan at a 2019 session of the United Nations’ Committee on the Peaceful Uses of Outer Space outlines future crewed landers, rovers, fuel cells, and eventually a lunar base.¹¹³ The president of JAXA also noted in October 2020 that “in future, JAXA might begin the development of a hydrogen fuel station to ensure a sustainable human presence on the Moon.”¹¹⁴ JAXA’s Space Exploration Innovation Hub Center was established in 2015 to collaborate with Japanese industry to support future space missions.¹¹⁵

Commercial

A Japanese commercial company, ispace, will deposit the Emirati Rashid rover on the Moon in 2022 on a SpaceX Falcon 9 rocket via their HAKUTO-R lunar lander. A second HAKUTO-R lander will launch in 2023, carrying an

ispace-designed rover.¹¹⁶ Future planned missions include rovers designed to survey for water and will acquire and sell data for future lunar missions. In the long term, ispace intends to develop an “industrial platform that enables stable lunar development by utilizing the water resources” identified beneath the Moon’s surface.¹¹⁷

In June 2019, JAXA signed an agreement with Toyota to develop a pressurized rover for the Moon. Currently, the project is working on developing a prototype and simulating different scenarios to confirm power and heat dissipation effects on the lunar surface. Dubbed the LUNAR CRUISER, this is the first step toward a semipermanent or permanent human presence on the Moon, and JAXA is beginning discussions with other industries to eventually bring this vision to life. The expected launch date of the LUNAR CRUISER is the latter half of the 2020s.¹¹⁸ The LUNAR CRUISER effort is separate from the LUPEX mission, but there are certainly similarities between the programs.

South Korea

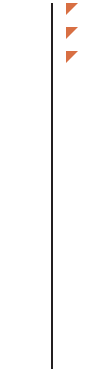
The first lunar mission of the Korea Aerospace Research Institute (KARI), the Korea Pathfinder Lunar Orbiter (KPLO), is expected to launch in August 2022 and will reach LLO in mid-December. KPLO is planned to orbit the Moon for at least one year.¹¹⁹ The orbiter will carry several South Korean instruments and one U.S. instrument. These instruments include two cameras to image the lunar surface, a gamma-ray spectrometer, a magnetometer, and NASA’s ShadowCam, which will search for ice deposits and is based off of the LRO.¹²⁰ Beyond developing national lunar capabilities, KPLO will utilize NASA’s Deep Space Network, through Delay/Disruption Tolerant Networking.¹²¹

KARI will continue to focus on the Moon as a national goal over the next decade. On March 25, 2021, South Korean president Moon Jae-in stated that “by 2030, we will achieve our dream of landing on the Moon by using our own launch vehicle.”¹²²

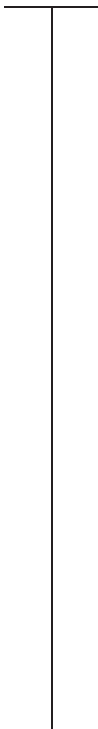
Thailand

In December 2020, Anek Laothamatas, Thailand’s minister of higher education, science, research, and innovation, announced an ambitious plan to go to the Moon by 2027.¹²³ A month later government officials held a Facebook Live

conference releasing details on the mission, including that there will be a series of developments to establish the Thai Space Consortium (TSC). TSC-Pathfinder development is underway, with launch scheduled no earlier than 2022. TSC-1 will include an optical instrument to observe the Moon from LEO no earlier than 2025. TSC-2 is the true “moonshot,” set to travel to cislunar space in 2027. TSC-3 through -5 are also planned, but no further details have been released.¹²⁴ Thailand is also currently moving to approve a Space Activities Bill, which will establish a new organization focused on space policy and regulations.¹²⁵



Indo-Pacific





AMERICAS

Canada

The Canadian Space Agency (CSA) created the Lunar Exploration Accelerator Program (LEAP), which provides funding to Canadian companies to develop technology for cislunar orbit or on the lunar surface. LEAP is part of a broader national effort to foster innovation in science and technology. Along with space, this includes artificial intelligence, machine learning, health, and robotics. LEAP's funding "support[s] the commercialization of innovative ideas from Canadian industry, including small and medium-sized businesses, in order to help them become an integral part of the growing new-space economy."¹²⁶ The total budget is \$150 million over five years. The program describes several areas for industry and academic contribution, including:

1. "science instrument(s) or technology destined for the Moon or beyond selected by a partner space agency";
2. "contributions to support the development of a proto-flight model, and its adaptation, delivery, integration, and launch";
3. "science initiatives targeting the Moon or beyond";
4. "mission concepts and technologies to position Canada for future lunar and deep-space exploration missions";
5. "technology development for the lunar supply chain"; and
6. a "micro-rover technology demonstrator."¹²⁷

Thus far, 14 contracts have been awarded to companies and universities in Canada.¹²⁸ Currently, there are two open funding opportunities.¹²⁹ CSA has also agreed to support the U.S.-led Lunar Gateway through the production of a smart robotic system known as Canadarm3, based on the Canadian-built robotic arms used for decades on the Space Shuttle and the ISS.

Mexico

Mexico will be launching its first national lunar mission on the Peregrine lunar lander built by the U.S. company Astrobotic. As previously noted, the Peregrine lander was delayed in production, causing a delay of launch until 2022.¹³⁰ Developed by the National Autonomous University of Mexico (UNAM), nine microbots will land on the Moon and measure the radioactivity of regolith dust.

The robots will "browse randomly and independently in the natural satellite until finding each other in a swarm that will be connected electrically and will form a solar panel."¹³¹ Data will then be communicated back to Earth for further study.¹³²

United States of America

The United States is also experiencing a resurgence of interest in the Moon. The government, primarily through NASA and the Department of Defense, is planning lunar and cislunar missions. This is incentivizing the growing commercial space sector within the United States to focus on the Moon as well. Notably, the recent National Space Priorities Framework released by the Biden administration in December 2021 included the goal to "advance a robust cislunar ecosystem" as a key priority.¹³³

Government – Civil

NASA has a long history of robotic and human exploration on the Moon. In 2020, NASA confirmed the presence of water on the lunar surface near the Moon's south pole.¹³⁴ Today, NASA has one ongoing mission in cislunar space, the Lunar Reconnaissance Orbiter (LRO). Launched in 2009, LRO is still operating in lunar orbit and has contributed to some groundbreaking discoveries, such as that the Moon is slowly drifting farther away from the Earth.¹³⁵

Artemis

NASA's Artemis program is the next evolution of the agency's human spaceflight and large-scale exploration.¹³⁶ Through Artemis, NASA will send humans back to the Moon, including the first woman and the first person of color. The plan is to establish sustainable cislunar and lunar infrastructure to enable future exploration through testing and demonstration of new technologies. NASA intends to utilize cislunar and lunar activities to prove technologies and methods that will one day support a human exploration mission to Mars. The Artemis program will also support the next generation of space technologies, allowing more companies and countries to invest and develop capabilities for the Moon and deep-space travel.

A key piece of the Artemis and Lunar Gateway missions will be Orion, a human-rated spacecraft for deep-space missions, including to the Moon. Orion will sit atop SLS and send U.S. astronauts back to the Moon. It is being built by Lockheed Martin and Airbus Defense and Space. NASA expects to spend \$9.3 billion on Orion through the



Orion Capsule

Source: NASA.

resources on the Moon, Mars, and asteroids.”¹³⁹ The Artemis Accords’ stance on space mining and resourcing has been publicly contested by China, Russia, and other nations who have a stricter interpretation of the Outer Space Treaty.¹⁴⁰

Lunar Gateway

There are several core mission elements designed to support the Artemis program. The first critical

piece of infrastructure is the Lunar Gateway, an orbiting space station that will utilize a near-rectilinear halo orbit (NRHO) and will serve as a logistics and transportation hub between Earth and the Moon. The NRHO is well suited for conducting missions to the lunar polar regions. The Lunar Gateway will also serve future deep-space human travel, including missions to Mars. The Power and Propulsion Element (PPE) and Habitation and Logistics Outpost (HALO) will be the first two modules launched, as they will directly support the missions to the Moon’s surface.¹⁴¹ While the PPE is being built by Maxar Technologies in the United States, HALO is being supported by ESA, as well as a U.S. company, Northrop Grumman. SpaceX was selected by NASA to launch these two modules in 2024 on a Falcon Heavy rocket.¹⁴²

As part of the next stage of the Lunar Gateway, NASA has established the Commercial Lunar Payload Services (CLPS) initiative. NASA has selected 14 U.S. commercial space companies to carry out lunar supply missions, including integration of payloads, mission operations, launch, and landing on the Moon. Along with NASA payloads, the

first (robotic) test, anticipated in March or April 2022. The second Artemis mission and first human mission is expected in May 2024, but a human landing on the Moon is not feasible until 2025 at the earliest. NASA must first successfully complete these first test missions, including at least one uncrewed landing on the Moon.¹³⁷

2022 | Artemis 1: Uncrewed Test Flight in Cislunar Space

2024 | Artemis 2: Crewed Test Flight in Cislunar Space

2025 | Artemis 3: Crewed Lunar Landing

2026 | Artemis 4: Gateway Assembly mission

2027+ | Artemis 5: Possible Crewed Lunar Landing with Mid-Way Stop at Gateway ¹³⁸

To support the Artemis program and enable greater international participation, NASA established the Artemis Accords, a set of principles the United States intends to use to support, govern, and guide future lunar missions. Fifteen countries have signed onto the Artemis Accords so far, including most countries that have pledged to participate in the Artemis program. As of January 2022, these countries include Australia, Brazil, Canada, Israel, Italy, Japan, Luxembourg, Mexico, New Zealand, Poland, the Republic of Korea, Ukraine, the United Arab Emirates, the United Kingdom, and the United States. Notably, the accords promise to lend reasonable emergency assistance—in the case of astronauts being stranded—and allow nations to “extract and utilize

Lunar Gateway with Approaching Orion Capsule

Source: NASA/Alberto Bertolin.



companies are encouraged to include other commercial payloads during a supply mission. The CLPS project has already contracted for several missions, including 18 payloads to be delivered to the Moon in 2022. The Polar Resources Ice Mining Experiment-1 (PRIME-1), for example, will be NASA's first ISRU mission on the Moon.¹⁴³

More payloads will follow in 2023, including almost 20 science and technology instruments and the Volatiles Investigating Polar Exploration Rover (VIPER).¹⁴⁴ VIPER is a mobile robotic rover that will explore the South Pole of the Moon to evaluate for future lunar activities and search for water deposits.¹⁴⁵ Astrobotic, a U.S. commercial space company, was selected through the CLPS program to deliver VIPER to the Moon on their Griffin lunar lander. Astrobotic recently announced that SpaceX's Falcon Heavy will launch the lander and rover to the Moon in 2023.¹⁴⁶

All these instruments, experiments, and tests will support the Lunar Gateway's first crewed mission, which will include a human-rated lunar lander so that the crew can venture to the lunar surface from the orbiting spacecraft. The Human Landing System program, part of NASA's Next Space Technologies for Exploration Partnerships (NextSTEP) private-public partnership model, chose SpaceX to develop the lander under a \$2.89 billion contract.¹⁴⁷ To support Artemis, new spacesuits called the Exploration Extravehicular Mobility Unit are also being developed. The first trip is expected to last about one week.¹⁴⁸

NASA will be returning to the Moon with the CAPSTONE mission. CAPSTONE is a 55-pound cubesat designed to test spacecraft-to-spacecraft navigation technology in cislunar space. This mission is critical to establishing the Lunar Gateway, NASA's next long-term orbiting space station.¹⁴⁹ CAPSTONE will be launched on the Electron space launch vehicle by the U.S.-New Zealand company Rocket Lab in March 2022.¹⁵⁰

Several other modules for the Lunar Gateway are under consideration and development. The current goal is a finished assembly by 2028 that will be approximately one-sixth the size of the ISS.¹⁵¹

Water and Ice

Another NextSTEP program is the Lunar IceCube nano-satellite that will evaluate ice deposits on the Moon, mapping them and providing further data for future missions. The spacecraft will accompany the first Artemis launch in early 2022.¹⁵² Lunar Flashlight will also be on board the Artemis-1 launch and will map the lunar south pole. Its mission includes using lasers to look for ice.¹⁵³

On the same flight, the Lunar InfraRed Imaging cubesat will conduct a lunar flyby and other technology tests to collect data in support of future lunar missions.¹⁵⁴

Two lunar missions were selected through NASA's small spacecraft program: Small, Innovative Missions for Planetary Exploration (SIMPLEX). LunaH-Map, the first mission, is a cubesat designed to orbit the Moon and evaluate how much water is in the permanently shadowed craters on the lunar surface. LunaH-Map is designed and built by Arizona State University and will launch on SLS in early 2022.¹⁵⁵ The second mission is the Lunar Trailblazer. Led by the California Institute of Technology, Lunar Trailblazer will also detect and map areas of water on the Moon's surface.¹⁵⁶ Launch is scheduled for February 2025.¹⁵⁷

Lunar Base Camp

The anticipated lunar base camp, designed for long expeditions on the surface, is the next big step after the first Artemis missions and the Lunar Gateway. The Base Camp will include an unpressurized (open-top) rover, a human-rated pressurized rover, a habitation module, power systems, and ISRU systems.¹⁵⁸ The Base Camp will be located at the lunar south pole in order to have access to potential water and mineral deposits.¹⁵⁹

Government – Military

Unlike many other countries, the United States has been clear about the military advantages of reaching the Moon and cislunar space.¹⁶⁰ The U.S. Space Force and NASA signed an MOU in September 2020 to cement continued partnership and the “furtherance of space exploration, scientific discovery, and security.”¹⁶¹ Since its founding, NASA has coordinated with other government agencies, including the Department of Defense, on science and technologies that have military value. Similarly, national security agencies share relevant discoveries or technologies with NASA. There are several relevant cooperative areas outlined in the MOU: “deep space survey tracking technologies to support extended SDA (space domain awareness) and NEO (near-Earth orbit) detection beyond geosynchronous orbit”; “capabilities and practices enabling safe, sustained near-Earth and cislunar operations”; “ride



Eyes on the Prize
The Strategic Implications of Outer Space and the Moon

By Spencer Kaplan

STRATEGIC IMPORTANCE OF OUTER SPACE AND THE MOON is a report by the Center for Strategic and International Studies (CSIS) and the Center for Space Policy Studies (CSPS) at Johns Hopkins University. The report examines the strategic importance of outer space and the Moon, and the implications of the Artemis program for the United States and its allies. The report highlights the need for a coordinated approach to space exploration and the importance of maintaining a leadership position in space.

The Moon is a strategically important location for the United States and its allies. It is a source of water, a source of minerals, and a source of scientific knowledge. The Moon is also a potential launch point for deep space exploration. The Artemis program is a key element of the United States' strategy to return to the Moon and establish a sustainable presence.

CSIS is a nonpartisan, nonprofit research organization that provides objective analysis and solutions to national security and public policy issues. For more information on the strategic importance of the Moon and cislunar space, read *Eyes on the Prize* by Spencer Kaplan.

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▶ For more information on the strategic importance of the Moon and cislunar space, read *Eyes on the Prize* by Spencer Kaplan.

The United States has been clear about the military advantages of reaching the Moon and cislunar space.



shares and hosted payloads to and beyond Earth orbit”; “interoperable spacecraft communications networks for Earth orbit and beyond”; and others.¹⁶²

Other Space Force personnel have written publicly about U.S. military operations in cislunar and lunar space, arguing that the Space Force should leverage its military expertise to support and develop future civil space activities.¹⁶³ The Outer Space Treaty forbids many military activities on celestial bodies, including establishing military bases or conducting military maneuvers.¹⁶⁴ However, some believe there still may be room to provide military support to civilian missions and remain in line with the United States’ international obligations though the treaty.¹⁶⁵

Spacepower, published in 2020, is the first doctrine published by the U.S. Space Force and declares that while today economic and military space activities are confined to the near-Earth, future technologies and capabilities will “expand the reach of vital National space interests to the cislunar regime and beyond.”¹⁶⁶ The document also uses the far side of the Moon as an example for how some parts of space can only be observed through orbiting spacecraft, and that there is desire to ensure full domain awareness.

Several ongoing projects funded or led by the Department of Defense, including within the Space Force, focus on cislunar space or the Moon. Of note is the U.S. Air Force contract with Rhea Space Activity in April 2020 to collect,

organize, and develop LUNINT. The first phase of the project was to develop a LUNINT dashboard, or virtual simulation of notable objects and their orbital details within cislunar space. This dashboard will later be integrated into mission control software suites that allow the U.S. military and allies to visualize and understand the space environment, enabling decisionmaking and planning for current or future capabilities.¹⁶⁷ In October 2021, Rhea Space Activity was awarded a contract extension for the project.¹⁶⁸

The Air Force Research Laboratory (AFRL) released *A Primer on Cislunar Space* in May 2021, which is directed at military space professionals as they develop operational concepts for the space domain. The paper also explains the challenges with the detection and tracking of spacecraft and how methods used in near-Earth orbits such as LEO, including traditional two-line elements (TLEs) used to describe an object’s trajectory, are useless in cislunar space given the introduction of a third body, the Moon. The report introduces cislunar space concepts and potential operations, including the unique physical dynamics of the cislunar and lunar regions and different capabilities cislunar spacecraft will require in comparison to spacecraft in near-Earth orbits.¹⁶⁹ AFRL is pursuing an experiment to develop and launch space-based sensors in cislunar space in order to demonstrate foundational SDA capabilities. This program is known as the Cislunar Highway Patrol System.¹⁷⁰ In a joint project with the Defense Advanced Research Projects Agency (DARPA), AFRL is working on the Defense Deep Space Sentinel (D2S2), a cislunar satellite designed to be highly mobile and carry a 20-centimeter camera to provide space domain and lunar surface awareness. The D2S2 satellite is expected to launch in late 2022.¹⁷¹

DARPA also has two separate relevant ongoing initiatives related to the Moon and cislunar space. Announced in February 2021, DARPA will pursue technologies for in situ manufacturing to produce large space or lunar structures. This program is called the Novel Orbital and Moon Manufacturing, Materials, and Mass-Efficient Design program and is in the early stages of development.¹⁷² In situ manufacturing is critical to overcoming the mass and volume limits of launch from the Earth’s surface. If structures or components could be developed in space or on the Moon, the ability to live and work in space will be more quickly achievable. The current program is split into three 18-month phases and will likely be completed in the mid to late 2020s.¹⁷³ The second DARPA effort is the Demonstration Rocket for Agile Cislunar Operations



program. This program intends to demonstrate nuclear thermal propulsion by 2025. Nuclear propulsion enables greater maneuver capabilities and provides operators with the ability to better monitor spacecraft in cislunar space or near the Moon.¹⁷⁴ In April 2021, DARPA selected Blue Origin, Lockheed Martin, and General Atomics for the first phase of the project.¹⁷⁵

Commercial

Separately from NASA or Department of Defense funding, several U.S. commercial space companies are working on cislunar or lunar missions.

United Launch Alliance has laid out its Cislunar 1000 roadmap, which intends to eventually sustain 1,000 people in Earth-Moon space. This self-sustaining plan relies on ISRU, among other critical technologies.¹⁷⁶ It is focused on developing a wide-reaching cislunar economy with other commercial companies, including Bigelow Aerospace, Astrobotic, and others.¹⁷⁷ Cislunar 1000 fits in well with the Lunar Gateway and NASA's plans for a sustainable future cislunar presence.

Astrobotic describes itself as a “Moon company” and has built its business case on lowering the barriers to access the Moon for science, exploration, and even to send keepsakes. Along with the Griffin lunar lander that will take NASA's VIPER to the Moon in 2023, Astrobotic has several planned lunar missions. The first is Astrobotic's Peregrine Mission One lunar lander that will carry a suite of scientific instruments and experiments from NASA and several international companies. Peregrine is expected to launch in 2022 and would make Astrobotic the first commercial company to reach the lunar surface. In 2023, Astrobotic plans to launch a mid-sized lunar rover, called Moon Ranger, to the lunar South Pole. This is also part of NASA's CLPS program. Moon Ranger will map the lunar surface, and that data will be used to build 3D maps in support of future lunar exploration missions.¹⁷⁸

Also sponsored by NASA's CLPS program, Intuitive Machines is competing with Astrobotic to be the first commercial lander on the Moon, and its lander will head to the South Pole to drill for ice. The Nova-C lander will “hop” around the lunar surface and access craters that have yet to be explored by robotic rovers.¹⁷⁹ Its launch date slipped from mid-2021 to early 2022 due to licensing and launch issues.¹⁸⁰

SpaceX's first cislunar space tourism mission—tentatively scheduled for 2023—will fly through cislunar space, orbit the Moon, and return to Earth. SpaceX's Starship space-

craft will take Japanese billionaire Yusaku Maezawa, who has purchased all seats on this first flight for himself and eight other artists, around the Moon on a trip that will last six to seven days.¹⁸¹



MIDDLE EAST & AFRICA

Israel

Cislunar and lunar landing efforts in Israel are largely led by an Israeli commercial company, SpacEL. SpacEL is responsible for the first ever nongovernmental lunar landing attempt. In 2019, the Beresheet 1 lunar lander successfully reached lunar orbit but was unable to land and instead crashed onto the Moon. SpacEL is working on the Beresheet 2 program to attempt once again to reach the lunar surface, but this time the mission will include two lunar landers and an orbiter.¹⁸² The two landers will be smaller than the original Beresheet 1 lander, and the orbiter will be in operation for a couple of years. SpacEL is looking for international partners to help financially support the program. According to the *New York Times*, the United Arab Emirates was one entity of seven interested in the program.¹⁸³ Beresheet 2 is currently scheduled to launch in 2024.¹⁸⁴

Another Israeli company, Helios, is betting on long-term sustainability on the Moon by building in situ resourcing and mining equipment. For their first test of Lunar Extractor-1, Helios will be ridesharing on Japanese company ispace's second mission to the lunar surface in 2023. Helios has also confirmed that Lunar Extractor-2 will be flown on another ispace mission to the Moon in mid-2024.¹⁸⁵

Turkey

In February 2021, Turkey's President Recep Tayyip Erdogan announced an ambitious plan for the Turkish Space Agency. This 10-year plan includes a lunar mission by 2028 that will consist of a rover deposited on the lunar surface by a Turkish national space launch vehicle. A 2023 test of the launch vehicle and lunar lander will support the 2028 mission. There are few additional details.¹⁸⁶

United Arab Emirates

In September 2020, Vice President Sheikh Mohammed bin Rashid announced the Emirates Lunar Mission. It will include a lunar rover, called Rashid, that will be equipped with two imagers (microscopic and thermal) and a probe that will "measure the electron density at the lunar surface," among other instruments.¹⁸⁷ Rashid is slated to be the smallest rover yet: coming in at around "20 inches long

and wide, and 28 inches tall, it will weigh approximately 22 pounds (10 kilograms) with its payload."¹⁸⁸ The lunar mission is scheduled to launch in 2022 on a SpaceX Falcon 9 rocket. The rover will be deposited at "an equatorial locale on the Moon's near side" by the HAKUTO-R lander, designed and operated by ispace.¹⁸⁹

Plans are already underway for a second rover to be launched in 2024 or 2025. Furthermore, the United Arab Emirates is evaluating how to expand its lunar program in other ways, to potentially include an orbiter, human exploration, and a lunar base fit for 1,000 people by 2040.¹⁹⁰



TRENDS ACROSS PLANNED MISSIONS

There is a flurry of activity planned for cislunar orbit or to pass through cislunar space on the way to the Moon's surface. Nations and companies alike see potential for new science, technology, and commerce. The "big three" space nations—China, Russia, and the United States—certainly have ambitious plans for cislunar space and the Moon. ESA also has a plethora of ongoing research and development projects dedicated to cislunar or lunar missions. Because ESA is funded by several nations and able to leverage the collective wealth and expertise of its members, it is no surprise that many European nations view ESA as the best way to achieve national civil space goals. Independently, there are many missions planned, including several highly capable programs from India, Japan, and the United Arab Emirates. The United Arab Emirates, in particular, has an ambitious plan to have 1,000 people live and work on the Moon by 2040. There are also many new endeavors from nontraditional space nations, such as Mexico, Thailand, and Turkey.

After a survey of the 106 cislunar and lunar activities from 19 nations and one multilateral governmental organization (ESA), it is clear that the current missions planned are to be the first of many, and therefore focus on gathering more information and data to support future missions. However, the data presented does not wholly capture the amount of cislunar and lunar missions and technologies currently planned. Data labeling was often based off the prioritization of one of several capabilities of a mission. For example, a lunar lander mission may also have a rover onboard or a secondary payload to gather regolith or drill for ice.

Science-gathering missions are the most common, with 12 dedicated to the search for water and ice. Transpor-

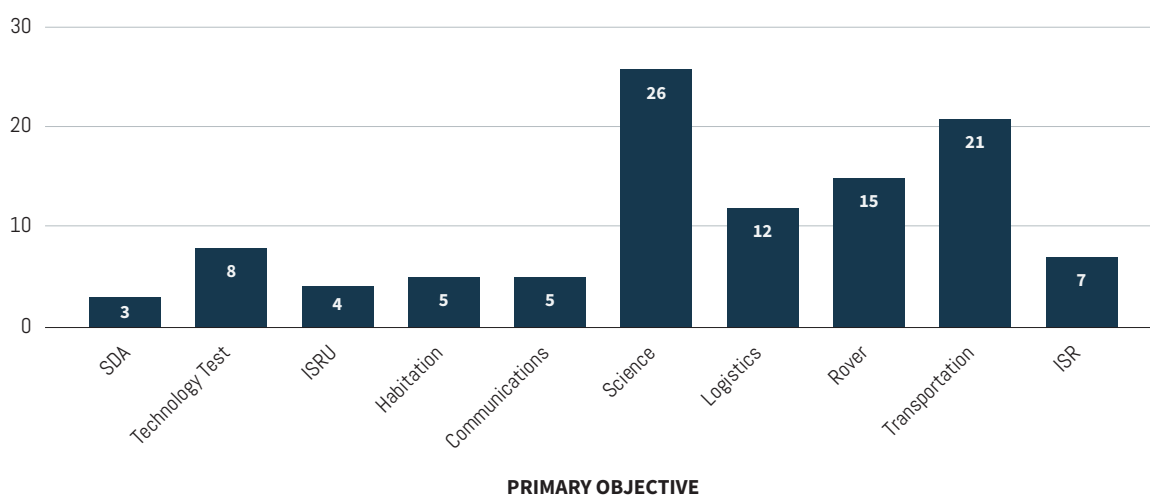
tation missions make up the second-most common type of mission, which is key for achieving sustainable long-term cislunar and lunar projects, such as the Lunar Gateway or lunar bases. The transportation category includes lunar landers, satellite busses for cislunar payloads, and launch vehicles or spacecraft specifically designed for lunar or cislunar missions. Rovers follow as the third-most popular type of mission, with 15 lunar rovers planned to launch in the next decade. These missions often include a secondary mission dedicated to science and data collection.

Surprisingly, there is a lack of situational awareness and communications missions planned. With so many lunar landers, rovers, and cislunar missions in development, nations will likely need more robust infrastructure for understanding the environment of cislunar space, as well as the ability to consistently communicate with assets in orbit around or on the Moon. Currently, China is operating the only communications relay satellite on the far side of the Moon, which supports China's ongoing Chang'e lunar missions. The U.S.-led Lunar Gateway will also provide significant communications capabilities in cislunar space. However, it is unclear if national efforts such as these will allow commercial missions or other nations to access communications capabilities.

There is a longstanding history of allowing commercial access to government-operated space infrastructure in near-Earth orbits, such as GPS for navigation and positioning. Creating commercial access to the communications, navigation, and space domain awareness (SDA) capabilities necessary for cislunar space might be the next evolution of

Figure 2: Cislunar and Space Missions

Source: Author's own research and analysis.





COUNTRY	TYPE	NAME	DATE
Russia	Government	Luna 25	2022
India	Government	Chandrayaan-3	2022
United States	Government	CLPS	2022
United States	Government	Lunar Icecube	2022
United States	Commercial	LunaH-Map	2022
United States	Commercial	Nova-C	2022
United States	Government	ShadowCam	2022
Australia	Commercial	Seven Sisters	2023
United States	Government	VIPER	2023
China	Government	Chang'e-7	2024
ESA	Government	European Prospect Drill	2025
United States	Commercial	Lunar Trailblazer	2025
Russia	Government	Luna 27/Luna Resurs	2026

government-supported space infrastructure. SDA is critical in near-Earth orbits, and the cislunar and low-lunar orbits require unique infrastructure and a new framework for understanding and evaluating where objects are located in space. Currently, for near-Earth orbits, satellites are given positions based on their relative position to Earth. This current Earth-based structure will be less effective in cislunar orbits, so a new internationally recognized data schema should be determined.¹⁹¹

Commercial companies are leading several lunar and cislunar missions, working to capitalize on the demand signal from interested governments. NASA, CSA, ESA, and others are contracting with industry or purchasing their launch vehicles, lunar landers, or rovers to deliver national capability to cislunar space or the Moon. Of the 106 missions surveyed, 24 are led by commercial industry. Notably, some countries are not pursuing a national lunar or cislunar capability, such as Israel and Ukraine, and commercial companies are leading the way for those nations to claim access to the Moon.

Overall, trends indicate more focus and investment in cislunar and lunar space activities by a wide range of governments and private companies. With little international law and regulation governing cislunar space or the Moon, international conversations in governing

▼ Table 2: Lunar and Cislunar Missions Focused on Water and Ice
Source: Author's own research and analysis.

bodies should begin to consider ways to protect the cislunar domain and the Moon, as well as coordinating activities to avoid accidents. Near-Earth orbits are facing difficult challenges with the sustainability of the domain and the growing amount of debris in valuable orbits. Serious conversations in multinational forums, such as the United Nations' Committee on the Peaceful Uses of Outer Space, should address and establish best practices and rules for operating in cislunar space sooner rather than later. Without this, the unsustainable pattern of behavior experienced in LEO, MEO, and GEO could be replicated in cislunar orbit.

Similarly, a clear, technically informed definition of cislunar space should be determined and accepted by the international community. Since cislunar capabilities are nascent, the lack of definition is not a major issue at present. However, in the future, if cislunar space is highly utilized by commercial and national capabilities alike, a commonly accepted definition of what is and is not considered cislunar space will allow the space community to establish and maintain best practices or rules of the road for operating in this regime.



China, Russia, and the United States are leading the way in cislunar and lunar development and in creating a sustainable presence. Many of the nations surveyed in this assessment are conducting cislunar and lunar research and development in coordination with major civil space program efforts from one of these three leading space powers. ESA, for example, is working with all three nations to further space exploration and technology. As cislunar and lunar plans further develop, most of the larger missions with greater infrastructure needs (e.g., communications, SSA, and navigation and timing) will be in partnership with at least one of the larger multinational efforts led by China, Russia, or the United States. Notably, China and Russia recently announced a search for partners for a joint lunar base.¹⁹² After close collaboration on other cislunar and lunar missions, a Russian-Chinese partnership with ESA is not difficult to foresee. As cislunar and lunar missions become more complex and last for longer durations, future missions will likely build on ongoing efforts and partnerships.

While China, Russia, and the United States may be looking at cislunar space and the Moon for national security gains, other nations have not stated or announced any similar plans or ideas. There is also a growing rhetoric in U.S. media that a new space race is beginning and

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A clear, technically informed definition of cislunar space should be determined and accepted by the international community.


that cislunar space and the Moon are perhaps once again the finish line. This is a mischaracterization of the current plans and missions dedicated to this space. No missions are directly countering one another, and there is no evidence that mission timelines have shifted or changed in order to “beat” another nation to the Moon. This assessment finds that the cislunar and lunar missions of other nations are led by national civil space agencies or by entrepreneurial new space companies, and many of these efforts are tied to ongoing cislunar missions by China, Russia, or the United States.

International partnerships are critical to the future of cislunar and lunar missions and, as seen in this assessment, often preferred. China, Russia, and the United States are all spearheading lunar or cislunar programs that involve several international partners. The United States, in particular, is prioritizing leadership of an international coalition for a more robust and sustainable lunar architecture through the Artemis Accords and Artemis program. Cooperation on the Lunar Gateway and the multiple internationally sponsored payloads or projects that will join NASA-led missions also showcase this priority. By working with allies and partners to set best practices and international standards, the United States will be able to influence and set favorable precedents for operating in cislunar space and on the Moon for decades to come.

However, international partnership amongst the “big three” global space powers is unlikely. Historical precedent proves that space cooperation can transcend global conflict, as was the case during the Cold War with partnership between the Soviet Union and the United States. Years of disagreement and refusal to compromise within multi-lateral fora, like the United Nations, does not indicate a willingness to partner on space missions. Furthermore, policies like the Wolf Amendment restrict NASA from cooperating with Chinese space programs and organizations.¹⁹³ Despite the great potential for interstellar global cooperation, the geopolitical tension, technological competition, and unwillingness to trust and compromise, will deter any substantial near-future partnerships between China, Russia, and the United States.

International partnerships, and partnerships between companies and governments, are leading this renewed pursuit to the Moon and into cislunar space. There appear to be three separating lines of effort, with some cross-pollution: the United States with allies and partners; China; and Russia. Organizations like ESA work with all three efforts, and the beginnings of a larger alliance between

China and Russia may emerge with the collaboration on a sustainable lunar presence. Policymakers should be aware that the first to set expectations or behaviors on the Moon or in cislunar space does not necessarily indicate these will become the rules, standards, or norms. Instead, policymakers worldwide should focus on consensual rules, standards, and norms from all space and emerging space nations, rather than risk a dichotomy of international governance in space.



No missions are directly countering one another, and there is no evidence that mission timelines have shifted or changed in order to “beat” another nation to the Moon.

About the Author

Kaitlyn Johnson is deputy director and fellow of the Aerospace Security Project at the Center for Strategic and International Studies. Ms. Johnson supports the team's strategic planning and research agenda. Her research specializes in topics such as space security, military space systems, and commercial and civil space policy. Ms. Johnson has written on national security space reorganization, threats against space assets, the commercialization of space, escalation and deterrence dynamics, and defense acquisition trends. She is also a cohost of the CSIS podcast **Tech Unmanned**, which features guests with both policy expertise and technical expertise in order to break through the national security jargon and technology hand-waving to get to the core of the technical realities of these emerging capabilities, benefits to development, and the barriers to success. Ms. Johnson holds an MA from American University in U.S. foreign policy and national security studies, with a concentration in defense and space security, and a BS from the Georgia Institute of Technology in international affairs.

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