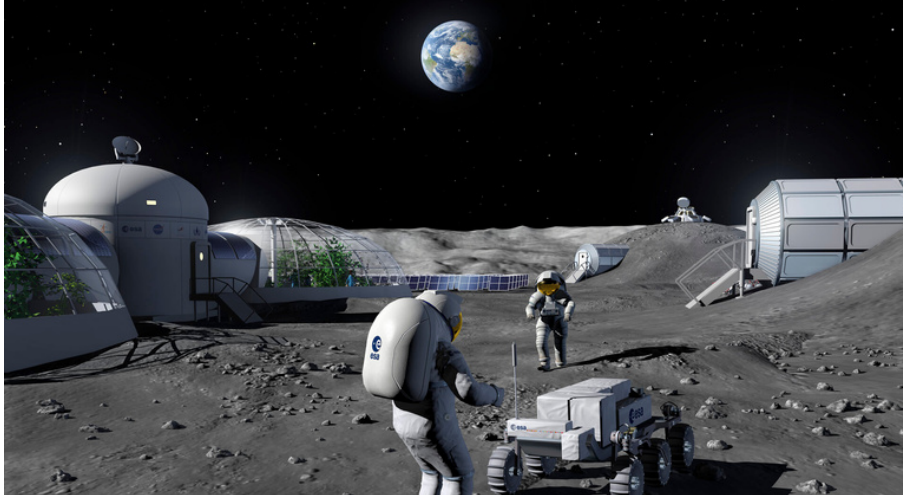


Destination Moon: Rediscovering Our Celestial Neighbor



Artist rendering of a Lunar Colony

The Moon has long been a source of fascination for humans. Since the first lunar landing in 1969, our understanding of our celestial neighbor has grown exponentially, yet in the decades since, lunar exploration has slowed down. That is now changing, as a new era of Lunar exploration is underway. In recent years, there has been a surge of interest in Lunar exploration, with countries old and new, along with private companies launching missions to explore Earth's nearest neighbor. Not only this, but governments are signing new agreements that will shape the way the Moon and space are explored for years to come. This renewed focus on the Moon and the Lunar Economy is not merely a revival of past glories, but a concerted effort to unlock its scientific and commercial potential, setting the stage for the future of space exploration.

Beyond the Space Race – Recent Lunar Surface Explorer Entrants

Following the 1976 landing of Luna-24 by the former USSR, there was a relative lull in the number of missions to the Moon. In the years since, while there has been a continued stream of orbiters, Lunar surface exploration has fallen quiet. This changed in the early 2000s as new players such as China and India began to launch unmanned missions. Not only this, but private companies for the first time also started launching unmanned landers of their own. Here is a brief recap of the recent activity that's been occurring and the players involved



Vikram Lander on the surface of the Moon taken by the Pragyaan rover. Credit: [ISRO](https://www.isro.gov.in)

India

India recently celebrated the landing of the Indian Space Research Organization's (ISRO) Vikram lander and Pragyaan rover as part of their [Chandrayaan-3 Mission](https://www.isro.gov.in/Chandrayaan-3) on August 23rd, 2023. This mission not only marked India's first lunar landing, but the first time a craft from any nation has performed a soft landing near the Lunar South Pole. The mission includes a variety of payloads carried between Vikram, Pragyaan, and the mission's propulsion module, which is staying in Lunar orbit itself to conduct science experiments. They include a Langmuir Probe to measure plasma density, a Surface Thermophysical Experiment to measure thermal properties of the Lunar polar region, an Alpha Particle X-ray spectrometer, a Laser Induced Breakdown Spectroscope, a Seismic Activity Instrument, and an experimental payload to study the "spectropolarimetric signatures of the habitable planet Earth in the near-infrared (NIR) wavelength range". The lander and the rover are both solar-powered and are designed to function for 1 Lunar day (14 Earth days).

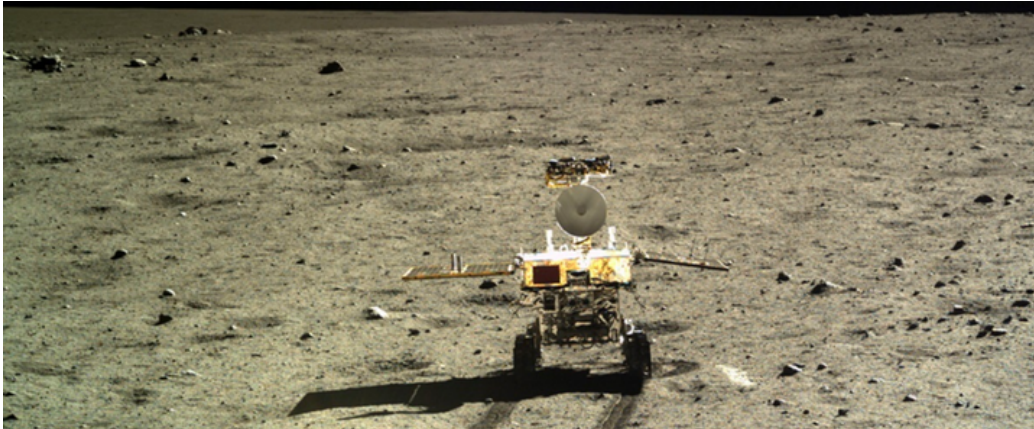
This mission builds upon the lessons learned from India's other recent Lunar missions. The Chandrayaan-3 mission in many ways is a repeat attempt of the [Chandrayaan-2](https://www.isro.gov.in/Chandrayaan-2) mission from 2019. While that mission's lander and rover crashed on impact, its orbiter, however, contained a multitude of payloads that are still operating as of publication (August 2023). In addition, India launched [Chandrayaan-1](https://www.isro.gov.in/Chandrayaan-1) which, along with carrying a suite of payloads, successfully impacted a lunar impact probe into the moon in 2008. Looking to the future, ISRO hopes to partner with the Japan Aerospace Exploration Agency (JAXA) to launch the [Lunar Polar Exploration Mission](https://www.isro.gov.in/Lunar-Polar-Exploration-Mission) (LUPLEX) to explore the lunar polar region for the presence and potential usability of water. While the mission is still in the works, it could launch as soon as 2026.



The Launch of Luna-25 Credit:Roscosmos/Vostochny Space Centre Handout

Russia

While Russia technically is not a new entrant to the Lunar surface exploration game, Russia's Roscosmos's recent Luna-25 mission was its first lunar mission since the fall of the Soviet Union. In fact, the name Luna-25 was chosen for the mission to connect it to the history of the Soviet Luna program of the 1960s and 1970s. The Luna-25 mission launched on August 10th, 2023. However, the lander crashed into the moon after a [failure occurred](#) during a burn designed to move the craft into a "pre-landing" orbit. Despite this setback, Roscosmos has plans to launch additional missions in the future. Keeping with the numbering convention, they have planned Luna missions 26-31. In particular, Luna-26 is planned to launch at some point in 2027 as a Lunar orbiter and Luna-27 will perform another [landing attempt in 2028](#). The remainder of the missions are planned out into the 2030s.

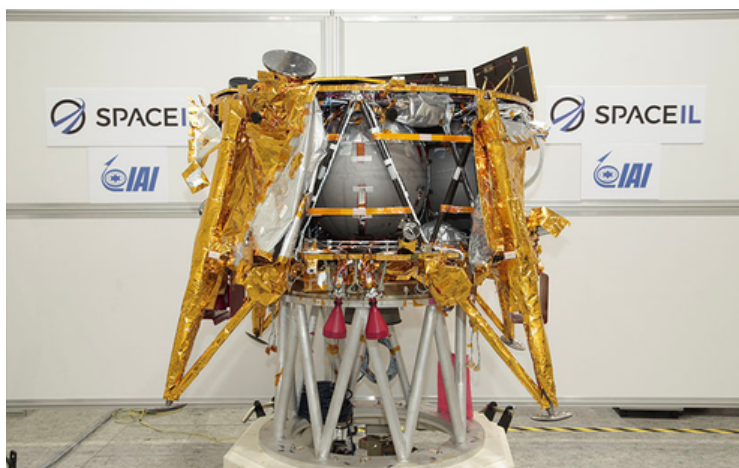


Chinese Yutu rover on the far side of the Moon Credit: [CNSA](#)

China

China's foray into lunar exploration has been marked by significant milestones, primarily led by the China National Space Administration (CNSA). Most recently China successfully launched their [Chang'e 5](#) mission in 2020. This mission's primary objective was to collect samples from the lunar surface and return them to Earth, which was successfully completed with the sample return's [capsule landing](#) in Mongolia. In addition to the sample return, the mission had a variety of cameras as well as a [Lunar Mineralogical Spectrometer](#) and [Lunar Regolith Penetrating Radar](#).

Prior to their sample return mission, China also had several notable achievements including their [Chang'e 4](#) and [Chang'e 3](#) missions, which launched in 2018 and 2013, respectively. Each of these included both a lander and a rover (Yutu and Yutu-2, respectively). Between the lander and the rover, the vehicles carried a suite of scientific payload experiments including various cameras, radars, and spectrometers, among others. Chang'e 4's mission was particularly noteworthy, as it was the first craft to land on the far side of the moon. To facilitate communications for this mission, China also launched the [Queqiao relay satellite](#) to the L2 Earth-Moon Lagrangian point. Prior to this, China also launched two orbiter missions Chang'e 1 and 2 in 2007 and 2010.



SpaceCell's Beresheet Lander prior to launch Credi: [IAI](#)

Israel and SpaceLL

Unlike the previous members of this list, SpaceLL is an Israeli private company, which attempted to land on the moon in 2019 with the [Beresheet lander](#). Launched on a SpaceX Falcon 9 rocket, this privately funded and built lander was intended for a two-day mission on the Lunar surface, given that a [lack of thermal control](#) would fry the lander's electronics. The payload included a magnetometer and [laser reflector](#), along with a large digital collection of data from various sources. Also included were genetic samples and [tardigrades](#). Ultimately, however, [the mission failed](#) due to an Inertial Measurement Unit gyroscope failing during the landing attempt.

Despite this failure, SpaceLL has started the development of its [Beresheet-2](#) mission. This mission, designed to be more ambitious than its first, will include an orbiter along with two landers.



The Hakuto-R lander being prepared for launch on a Falcon 9 rocket Credit: [ispace](#)

Japan and the United Arab Emirates

In a joint mission launched in December 2022, the Hakuto-R mission was launched on a Falcon 9 rocket. This mission was unique in that it contained a lander built by a Japanese private company, [ispace](#), as well as the Emirates Lunar Mission Rashid rover built by the United Arab Emirates, and the SORA-Q “[Lunar Robot](#).” Unfortunately, the mission failed when [the lander crashed](#) into the Moon due to the craft running out of fuel.

The [Rashid rover](#) was to be the UAE’s first mission to the Moon and was equipped with several high-resolution cameras, along with a microscopic camera and a thermal imaging camera. Further, it carried a Langmuir probe to study Lunar plasma in an attempt to explain why Moondust is sticky.

The Lunar Robot was built by Japanese toy manufacturer Takara Tomy in partnership with the JAXA. This lunar robot, which takes inspiration from toy designs, was meant to test two mobility designs, along with serving as a data collector, as it was to be dropped from the lander right before landing to capture the moment the lander.

Despite these failures, JAXA is aiming for the moon once again. While the launch was scrubbed due to weather on August 28th, 2023, JAXA is set to launch a new lander to the moon called the [Smart Lander for Investigating the Moon \(SLIM\)](#). According to JAXA, the purpose of this mission is to demonstrate a high-precision landing on the moon, aiming to land within 100 meters of its target on the surface. This compares with more conventional landings, which aim to land within several kilometers of the intended target.

The Artemis Program – An International Approach

In addition to the new entrants, some more traditional players also have their sights on the Moon. With the end of the Space Shuttle program, NASA shifted its focus once again to the Moon. To return to the Moon, NASA created the [Artemis program](#) (so named because in mythology Artemis is the sister of Apollo). To carry out its vision, NASA decided to collaborate with a wide array of commercial and international partners to build the various components needed for its program.

While NASA used more traditional vendors such as the United Launch Alliance (ULA) to build its new moon rocket, the Space Launch System (SLS), it did something different for its Orion crew vehicle. The vehicle, which will be stacked on top of the SLS stack, is part of the rocket that astronauts will live in and is being built in partnership with the European Space Agency (ESA), with ESA building the service module component of the craft. Additionally, as part of its lunar exploration plans, NASA intends to build a space station in orbit around the Moon. Called [Gateway](#), this orbiting station will also be built with the cooperation of several international partners including ESA, JAXA, and the Canadian Space Agency, as well as several private companies such as SpaceX, Maxar, Boeing, Northrop Grumman, and Aerojet Rocketdyne, among others. Adding to this, NASA is partnering with private companies such as SpaceX and Blue Origin to build the next generation of lunar landers as part of the [Human Landing Systems \(HLS\)](#).

A Long-Term Vision – The Artemis Accords

NASA's vision, however, doesn't simply consist of plans to build and launch equipment to the Moon. In 2020, The United States, co-led by NASA and the US State Department, announced the Artemis Accords. These accords lay out a set of principles designed to guide [civil space exploration and use](#) for the future, and cover a wide array of obligations and responsibilities that the signatory nations agree to uphold in their exploration of space.

The Accords have ten main areas of focus, chief among them that signatories affirm any activities carried out in the exploration of space should be done exclusively for peaceful purposes. This core principle is not new; rather it reaffirms a focal point of past space agreements, in particular the Outer Space Treaty of 1967, which at the height of the Cold War also made [the peaceful exploration and use of space](#) a priority. In addition to this core principle, the accords cover a wide array of topics including transparency in space operations; interoperability; emergency assistance to personnel in space in distress; registering space objects; releasing and sharing scientific data; protecting space heritage; the use of space resources; notifications of in-space activities; and management and disposal of orbital debris.



8 countries signing the Artemis Accords Credit: NASA TV

As of writing (August 2023), there are [28 countries](#) that have signed the accords: Argentina, Australia, Bahrain, Brazil, Canada, Columbia, Czech Republic, Ecuador, France, India, Israel, Italy, Japan, Luxembourg, Mexico, New Zealand, Nigeria, Poland, the Republic of Korea, Romania, Rwanda, Saudi Arabia, Singapore, Spain, Ukraine, United Arab Emirates, the United Kingdom, and the United States. Mike Gold, who at the time of the introduction of the accords was acting associate administrator for international and interagency relations, stated that “fundamentally, the Artemis Accords will help to avoid conflict in space and on Earth by strengthening mutual understanding and reducing misperceptions. Transparency, public registration, deconflicting operations – these are the principles that will preserve peace. The Artemis journey is to the Moon, but the destination of the Accords is a peaceful and prosperous future.”

Once the finish line, the Moon has transitioned into a bustling hub of activity drawing interest from a diverse set of international players, both public and private. With the broader space industry once again looking beyond Earth’s orbit to the Moon, the near future has much in store.

With this renewed interest, along with the framework that the Artemis Accords are providing, the future of Lunar exploration and beyond is no longer about who can race to the heavens first, but rather is being shaped by the promise of scientific discovery and the potential for future opportunities.