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Rajaram Nagappa
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Moon Missions: The Way Ahead

National Institute of Advanced Studies
Bengaluru, India

NIAS/CSS/ISSSP/U/RR/10/2023

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Abbreviations

APSCO	Asia Pacific Space Cooperation Organization
BIRCHES	Broadband InfraRed Compact High Resolution Exploration Spectrometer
CAPSTONE	Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment
CHACE-2	Chandra Atmospheric Composition Explorer–2
CHM	Common Heritage of Mankind
CLASS	Chandrayaan-2 Large Area Soft X-ray Spectrometer
CNSA	Chinese National Space Administration
CuSP	Cube Sat for Solar Particles
DEM	Digital Elevation Model
DFRS	Dual Frequency Radio Science Experiment
DFSAR	Dual frequency Synthetic Aperture Radar
EL3	European Large Logistics Lander
EQUULEUS	EQUilibriUm Lunar-Earth point 6U Spacecraft
ESA	European Space Agency
ICPS	Interim Cryogenic Propulsion Stage
IIA	Indian Institute of Astrophysics
IIRS	Imaging Infra-Red Spectrometer
ILRS	International Lunar Research Station
ISRO	Indian Space Research Organisation
ISRU	In-situ Resource Utilization
ISS	International Space Station
JAXA	Japanese Aerospace Exploration Agency
LCROSS	Lunar Crater Observation and Sensing Satellite
LRO	Lunar Reconnaissance Orbiter
LunaH-Map	Lunar Hydrogen Mapper
LunIR	Lunar Infra Red Imaging
LUPEX	Lunar Polar Explorer
LVM3	Launch Vehicle Mark 3

KPLO	Korea Pathfinder Lunar Orbiter
MiniSAR	Mini Synthetic Aperture Radar
MIP	Moon Impact Probe
NASA	National Aeronautics and Space Administration
NEA	Near Earth Asteroid
OHRC	Orbiter High Resolution Camera
OMOTENASHI	Outstanding Moon Exploration Technologies
OST	Outer Space Treaty
ROK	Republic of Korea
SING	Spectrographic Investigation of Nebular gases
SLIM	Smart Lander for Investigating Moon
SLS	Space Launch System
SMART	Small Missions for Advanced Research in Technology
TMC	Terrain Mapping Camera
U	One unit of Cubesat measuring 10cm x 10cm x 10cm (can be sized 1U-6U)
UNOOSA	United Nations Office for Outer Space Affairs
UNCOPUOS	UN Committee on Peaceful Uses of Outer Space
VIPER	Volatiles Investigating Polar Exploration Rover
XSM	Chandrayaan-2, called Solar X-ray Monitor

Executive Summary

After the Apollo missions as well as the other robotic missions of US and Russia (then USSR) of the 1970s, there has been a lull in the lunar exploration activity. In fact, there were no international lunar missions in the 1980s and only three missions in the 1990s. However, interest in the lunar exploration picked up momentum in the 21st century with half a dozen orbiter and impactor missions in the first decade followed by more focused approach in the subsequent years. In 2008, India became the fourth individual country to reach the lunar surface when the Moon Impact Probe (MIP) carried by its Chandrayaan-1 spacecraft to lunar orbit, made the intended hard landing on the lunar surface near Shackleton crater in the South Polar region of the Moon. Later, the conclusive evidence of water on the Moon provided by Chandrayaan-1 was seen as a pathbreaking discovery.

The missions from 2010 onwards included orbiters, landers and rovers as well as sample collection missions. In fact, Chinese spacecraft Chang'e 4 created history by making a soft landing on the far side of the moon and deploying the Yutu-2 rover. And, India's Chandrayaan-2 spacecraft has completed nearly four years in lunar orbit and continues to provide a variety of science data on various aspects of the Moon. The missions of the previous decade have confirmed the presence of water ice in the south polar regions of the moon and provided an impetus for crewed missions to the moon to further explore and find the means to stay, harvest and process the resources and plan for missions beyond the moon. Lunar resources which are quite abundant include volatiles like water, minerals which contain Silicon, Oxygen, Calcium, Magnesium, Aluminum as well as Titanium and specifically Helium-3, which is being perceived as a relatively clean fuel for yet to be developed nuclear fusion reactors. The mining, processing and utilization of those resources on the lunar surface itself has the potential to reduce the cost of a sustainable presence on the Moon and to venture beyond.

A number of countries and space agencies are in the process or have plans for orbital as well as lander/rover type of missions and the calendar of activities extends to the end of the decade. China has planned further Chang'e missions leading to technologies for setting up a lunar station by 2028. India's Chandrayaan 3 mission is slated for this year and India has plans in collaboration with Japan for a robotic lander/rover mission. Russia is also resuming its Luna missions and ESA is planning missions for studying In Situ Resource Utilization (ISRU) as well as EL3 lander mission.

In respect of crewed missions, the US was first off the block with its super heavy Space Launch System (SLS) capable of putting the crewed Orion Spacecraft on a trans-lunar trajectory. The first successful flight of the vehicle happened on November 16, 2022 and paved the way for further crewed missions around the moon and return followed by missions when astronauts will set foot on the lunar soil. The human lunar exploration program of the US is fashioned under the Artemis Programme and comprises a lunar gateway, lander and rover with frequent crew landing and departure from the moon while carrying out mission related tasks.

Pertaining to the further focused human exploration of the Moon, maintenance of a sustainable human presence there for the in-situ utilization of extracted lunar resources, two new legal instruments, namely, 'Artemis Accords' and 'International Lunar Research Station Guide for Partnership' have emerged. The purported goal of these two initiatives is the orderly development and utilization of lunar resources through international cooperation.

To further international cooperation in lunar exploration, NASA in October 2020 announced the establishment of Artemis Accords. The Accords, which is a non-binding agreement, will be a guide to future cooperative activities. Bilateral agreements between NASA and participating countries will describe responsibilities and legal provisions, while at the same time participating partners will make sure their activities comply with the provisions of the accords. The Accords aims to bring together like-minded states in the realization of 'a set of goals, principles, and practices to advance mutually agreed governance systems for the acquisition of resources and benefits from the lunar surface'. In short, according to NASA, the Artemis Accords reinforce and implement the 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, otherwise known as the Outer Space Treaty (OST). The principles to which the Accord subscribes to, are as under:

- Peaceful Exploration: All activities conducted under the Artemis program must be for peaceful purposes
- Transparency: Artemis Accords signatories will conduct their activities in a transparent fashion to avoid confusion and conflicts
- Interoperability: Nations participating in the Artemis program will strive to support interoperable systems to enhance safety and sustainability
- Emergency Assistance: Artemis Accords signatories commit to rendering assistance to personnel in distress
- Registration of Space Objects: Any nation participating in Artemis must be a signatory to the Registration Convention or become a signatory with alacrity
- Release of Scientific Data: Artemis Accords signatories commit to the public release of scientific information, allowing the 'whole world to join on the Artemis journey'
- Preserving Heritage: Artemis Accords signatories commit to preserving outer space heritage
- Space Resources: Extracting and utilizing space resources is key to safe and sustainable exploration and the Artemis Accords signatories affirm that such activities should be conducted in compliance with the Outer Space Treaty
- Deconfliction of Activities: The Artemis Accords nations commit to preventing harmful interference and supporting the

principle of due regard, as required by the Outer Space Treaty

- Orbital Debris: Artemis Accords countries commit to planning for the safe disposal of debris

While the Artemis Accords claims to be in line with and reinforce the OST, the significant difference to note here is that it is a bilateral agreement between NASA and signing countries/space agencies. Also, some divergences from OST are present in the Artemis Accords. OST advocates a principle of non-appropriation on moon and other celestial bodies and the question that arises is, if resource extraction from a particular location by any state constitutes appropriation. There are clauses like safety related exclusion zones and commercial extraction of lunar resources which are not in tune with Moon being common heritage of mankind. Equitable distribution of resources is another contentious issue. Notwithstanding these differences, as of April 2023, twenty three states/space agencies are signatories to the Artemis Accords.

Some states have passed legislation relating to resource extraction and their commercial use. In 2015, the US passed the Space Exploration and Utilization Act, which will facilitate commercial exploration and commercial recovery of space resources by US citizens. Luxembourg, UAE and Japan have passed similar legislation.

The International Lunar Research Station (ILRS) unveiled in 2021 is another cooperative initiative to explore the moon. The effort is promoted by China and Russia and details of ILRS are just evolving. The ILRS, according to Chinese National Space Administration (CNSA), is complex of experimental research facilities to be constructed with possible attraction of partners on the surface and/or in the orbit of the Moon designed for multi-discipline and multi-purpose scientific research activities, including exploration and use of moon, moon based observation fundamental research experiments and technological verification, with the capability of long term unmanned operation with the prospect of subsequent human presence. CNSA will soon set up an organisation to oversee and coordinate the China-led International Lunar Research Station.

Lunar missions hold a lot of promise as moon and its resources will be the gateway to Mars and other deep space missions. Moon will function as the base camp for ferrying humans and resources for a future Mars settlement.

Moon missions are tricky as evident by the last-minute failed attempt to make soft landing of the Hakuto Mission lander on the moon by Japanese company ispace as recently as April 26, 2023. Notwithstanding occasional technical glitches, missions to the moon will progress and India will be an important player. India will probably be in a position to undertake human landing and exploration of the moon by the 2030. India has been equipping itself for lunar exploration through a series of missions and enabling technologies including reusable launch vehicle, deorbit and recovery of space capsules, rendezvous and docking. A crewed space station is also part of the plan and these will form the building blocks for human lunar exploration by India in time to come.

It must be noted that the moon agreement of the OST is not universally popular and has been ratified by only 18 states. India has signed it but not ratified it. Under the circumstances, technologically and functionally as well as from economic considerations, it makes sense for India to be among leading players in planning, implementing missions to the moon and partner in resource extraction and utilization. In this India will bring to the table its own technological contributions and at the same time partner with other countries in newer technology realization. The study recommends India joining the Artemis Accords and in the bilateral agreement with NASA build in the necessary clauses safeguarding the interests of India.

Note: This article was prepared before India's recent decision to join the Artemis Accords. India signed the Artemis Accords in Washington in June 2023. India has become the twenty seventh signatory to the Accords. Content, views and analysis brought out in the report are still valid and may be helpful during further discussions.

History of Lunar Exploration, Lunar Resources and Achievements of Chandrayaan

B R Guruprasad*

Introduction

Moon is the nearest celestial body to Earth and from the surface of the Earth, humans have enjoyed the beauty of the Moon, perfected calendars based on lunar phases, used its position in the sky for navigation and utilised moonlight for night time mobility. Though telescopic observation enabled humans to broadly understand the nature of the Moon, robotic spacecraft that passed by Moon, reached its surface, carried wheeled robotic vehicles for *in situ* exploration of the lunar surface or brought back lunar rock and soil samples, have been responsible for the giant leap in our knowledge base about the moon. Besides, Moon is the only celestial body on which humans have set foot.[1] As of March 2023, more than 100 spacecraft launch attempts had been made for exploring the Moon, mostly by USA and the former USSR and the rest being China, European Space Agency, Japan, India, Israel and South Korea. It is generally opined in the scientific community that a detailed understanding of the Moon provides essential inputs to our comprehension of the evolution of our solar system in general and Earth in particular.

Figure 1: The Moon *(Source: NASA)*

The first phase of lunar exploration began in the early years of the space age itself with the unintended flyby of the Moon by Soviet *Lunik 1 (Luna 1)* in January 1959 at a distance of about 6000 km as it missed its goal of impacting on the lunar surface. The subsequent *Luna 2* became the first man made object to reach the Moon as it impacted on the lunar surface on September 13, 1959. Following this, *Luna 3* sent the pictures of the far side of the Moon which enabled humans

* Adjunct Faculty, ISSSP, National Institute of Advanced Studies, Bengaluru.

1 May Andrew, "Every Mission to the Moon: A Favourite Target for Space Travel", space.com, October 29, 2021 (https://www.space.com/all-moon-missions)

to take a glimpse of the lunar far side for the first time in October 1959. After a series of failures, *Luna 9* gently landed on the Moon surface in February 3, 1966, while in the same year *Luna 10* became the first artificial satellite of the Moon and explored Moon through remote sensing[2].

Figure 2: Lunar far side as seen by Luna 3 *(Source: NASA)*

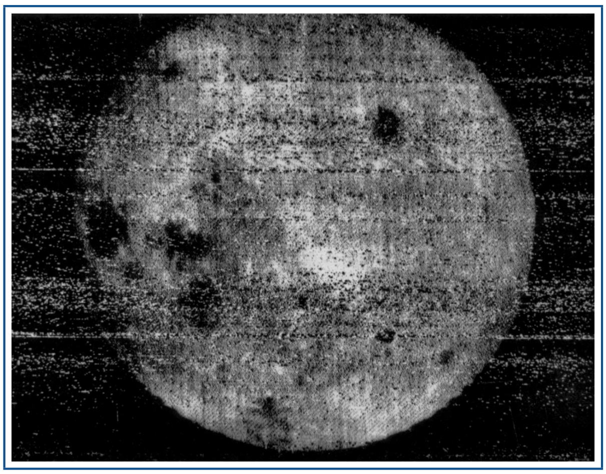
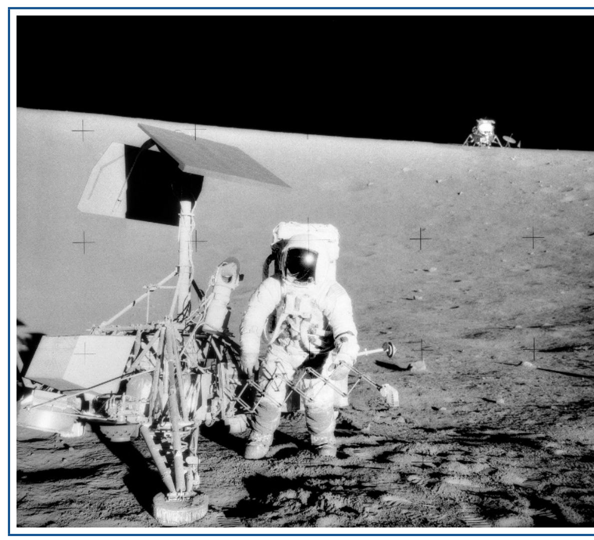


Figure 3: A model of Luna 9 Lander *(Source: Stanislav Kozlovskiy)*

During the 1960s 'Moon Race' with USSR, the United States demonstrated its ability to impact the lunar surface through its *Ranger* series of spacecraft, its ability to soft land on the Moon through its *Surveyor* spacecraft and its ability to generate high resolution images of the Moon through its *Lunar Orbiter* Spacecraft. More importantly, the US successfully landed 12 of its astronauts on the lunar surface and safely brought them back[3].

Figure 4: Surveyor 3 Spacecraft being inspected by an Apollo 12 Astronaut on the moon *(Source: NASA)*



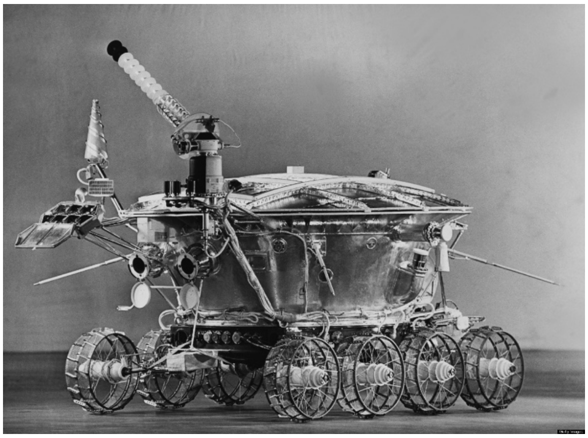
Though USSR was never able to land its cosmonauts on the Moon, nevertheless it was able to get small quantity of lunar rock and soil through its three Luna sample return spacecraft and conducted *in situ* exploration of the Moon through two of its *Lunakhod* rovers. The first phase of lunar exploration ended with the return of *Luna 24* capsule carrying precious lunar samples back to Earth in August 1976[4].

2 Asif A Siddiqi, Beyond Earth: A Chronicle of Deep Space Exploration, 1958-2016, NASA History Division, Washington DC

3 ibid

4 ibid

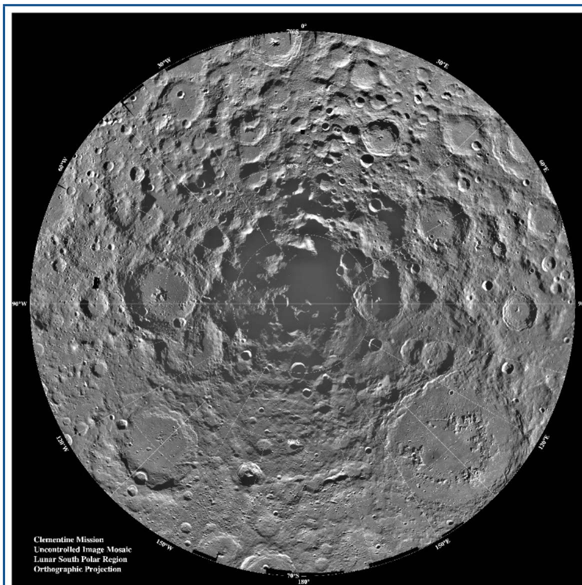
Figure 5: Lunakhod Rover *(Source: NASA)*



After a hiatus of about 14 years, it was Japan which began the second phase of Lunar exploration which is still continuing. Following the deliberate impact of the small Japanese *Hiten* spacecraft on the lunar surface in February 1992, the United States launched its small *Clementine* spacecraft whose data later appeared to indicate the presence of water ice in the lunar polar areas. To investigate further, the US sent its *Lunar Prospector* spacecraft to Moon which provided evidence that suggested the presence of water ice in the polar areas of the Moon[5].

In the new millennium, the European Space Agency (ESA) launched its *SMART-1* spacecraft to Moon in September 2003 and after travelling at a snail's pace using its ion engine, the spacecraft entered lunar orbit in November 2004, studied Moon's topography and surface texture through its instruments. Besides, it mapped the surface distribution of some minerals including Pyroxenes, Olivines and Feldspar. Following the completion of its primary mission, it impacted the lunar surface in September 2006. In September 2007, Japan's second lunar exploration spacecraft *Selene (Kaguya)* was launched and that lunar orbital mission was a success with the spacecraft sending information on the global distribution of Olivine on the lunar surface as well as its origin. As if to challenge the established players, China too launched its first mission to Moon, *Chang'e-1* in October 2007, whose success heralded four more highly successful *Chang'e* spacecraft missions over the subsequent fourteen years with their conspicuous achievements. Equipped with a microwave radiometer, *Chang'e-1* became the first lunar robotic spacecraft to conduct microwave remote sensing of the Moon[6].

Figure 6: Lunar South Polar Region as seen by Clementine Spacecraft *(Source: NASA)*



Along with these missions of early 21st century, India too launched its maiden mission to Moon – *Chandrayaan-1* – on October 22, 2008 carrying Indian and foreign payloads. With the deliberate crashing of the TV set sized *Moon Impact Probe* on the lunar surface on November 14, 2008, India became the fourth individual country to reach the lunar surface[7]. Though *Chandrayaan-1* mission

5 Op. cit. 4

6 ibid

7 ibid

ended prematurely, the data it had collected earlier resulted in the pathbreaking discovery of water on the moon conclusively[8]. During that decade, the United States also launched its *Lunar Reconnaissance Orbiter* which helped discover new surface features of the Moon besides helping scientists to make an important discovery that shaded locations inside the pits on the lunar surface could have tolerable temperatures. This discovery could become useful for future lunar exploration and sustained presence. *Lunar Crater Observation and Sensing Satellite (LCROSS)*, which was launched with LRO, was successful in confirming water ice in the lunar crater *Cabeus*[9].

Figure 7: An artist's impression of Chandrayaan-1 around the moon *(Source: ISRO)*

Though in the second decade of the 20th century United States, Israel, Japan, China and India launched spacecraft to moon to continue the robotic lunar exploration, it is China which has scored significant success in this domain. As part of China's perseverant endeavour to explore the Moon, *Chang'e-2* orbiter further explored the Moon and its successor, *Chang'e 3* sent its lander to soft land on the near side of the Moon successfully in December 2013. The *Yu Tu* rover carried by *Chang'e 3* lander conducted in situ exploration of the landing area. Five years later, *Chang'e 4* became the first spacecraft to land on the far side of the Moon and the Yu Tu 2 rover which it carried conducted *in situ* observation of that pristine surface. Finally in December 2020, *Chang'e 5* brought back the lunar soil samples to Earth successfully[10, 11]. Though India's *Chandrayaan-2* was not successful in its attempt to make a soft landing on the lunar surface in September 2019, its orbiter is continuing the task of remotely sensing the moon with its eight payloads[12,13].

8 Jefferson Morris, "Water, Water ....", Aviation Week and Space Technology, September 28, 2009

9 Op cit. 6

10 Adam Mann, "China's Chang'e Programme: Missions to Moon", space.com, Feb 01, 2019 (https://www.space.com/43199-chang-e-program.html)

11 Planetary Society, "Chang'e 5: China's Moon Sample Return Mission", (https://www.planetary.org/space-missions/change-5)

12 Stephen Clark, "India launches robotic mission to land on the moon", spaceflight Now July 22, 2019 (https://spaceflightnow.com/2019/07/22/india-launches-robotic-mission-to-land-on-the-moon/)

13 Stephen Clark, "NASA lunar orbiter to image Chandrayaan 2 landing site", Spaceflight Now, September 12, 2019 (https://spaceflightnow.com/2019/09/12/nasa-lunar-orbiter-to-image-chandrayaan-2-landing-site-next-week/)

Figure 8: Yutu-2 Rover *(Source: CNSA)*

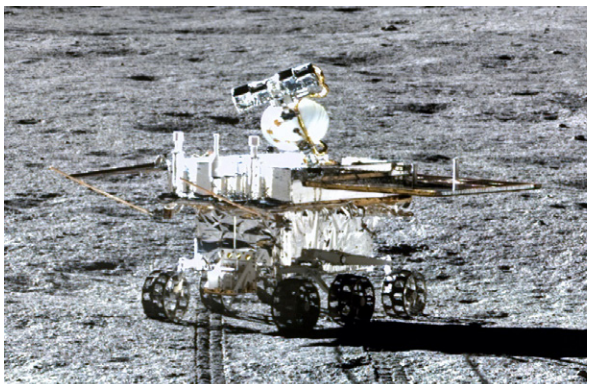


Figure 9: Chandrayaan-2 Lander mounted on top of the orbiter *(Source: ISRO)*

Figure 10: An Artist' view of Chang'e 5 lift-off from the Moon *(Source: CNSA)*

On June 28, 2022 NASA launched the 25 kg CubeSat *Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE)* to test and verify the calculated orbital stability planned for the lunar *Gateway* space station that is a crucial element of the Artemis programme. Of the 10 CubeSats launched onboard *Orion/Artemis 1* mission, some have been successful while others have failed. South Korea's maiden lunar mission *Danuri*, a lunar orbiter spacecraft and a technology demonstration mission, is active[14].

Human spaceflight Missions to Moon

Notwithstanding the significant achievements of robotic lunar spacecraft, the nine *Apollo* spacecraft that either carried humans to lunar orbit or landed them on Moon, have provided far more confidence to human society on travelling to other worlds in space, while at the same time enabled humans to conduct *in situ* exploration of the lunar surface in a more flexible way. The picture of 'Earthrise' from sent by *Apollo 8* astronauts from lunar orbit became an iconic image of the *Apollo* programme and made humans to seriously think about the necessity of carefully

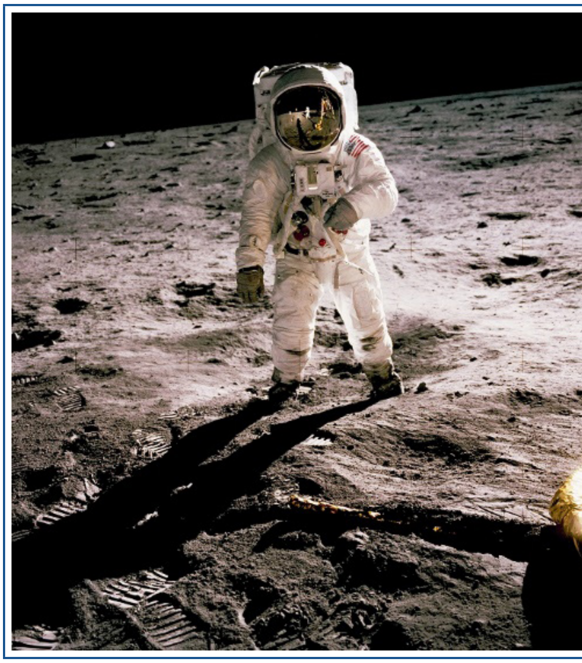
14 Brandon Specktor, "South Korea's Lunar Orbiter Unveils Jaw Dropping Images of Earth and the Moon", Livescience.com, January 25, 2023 (https://www.livescience.com/south-korea-danuri-orbiter-moon-images)

preserving their unique planet, Earth. Twelve *Apollo* astronauts who walked on the Moon and some of them who explored the lunar surface through a wheeled vehicle, have brought back about 382 kg of lunar rock and soil samples. The analysis of these samples has enabled scientists to propose a revolutionary theory about the genesis of the Moon as a result of a Mars sized object coming and colliding with the Earth during the latter's infancy, which is widely accepted by the scientific community.

Figure 11: Earth as seen from Lunar orbiting Apollo 8 Astronauts *(Source: NASA)*

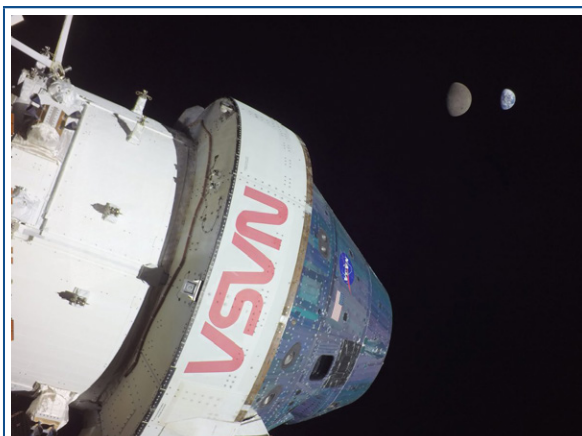
The successful uncrewed launch of an *Orion* capsule to Moon November 16, 2022 as part of *Artemis 1* mission almost 50 years after the return of the last Apollo astronauts to Earth in December 1972, its subsequent orbital flight around the Moon followed by its safe return to Earth about 26 days after its launch, has signified the dawn of a new era in lunar exploration. With its ability to carry four astronauts to lunar orbit and then bring them back to Earth, *Orion*

Figure 12: Man on the Moon *(Source: NASA)*



capsule is an important element of the NASA's Artemis programme that intends to establish a sustainable human presence on the lunar surface for exploration and utilisation of lunar resources as well as utilising Moon as a staging post for reaching Mars, asteroid belt and beyond[15].

Figure 13: Orion Spacecraft in Lunar Orbit with Moon and Earth in the background *(Source: NASA)*



15 Mike Wall, "NASA is over the Moon with the success of Artemis 1 Orion Test Flight", space.com, December 12, 2022 (https://www.space.com/nasa-celebrates-artemis-1-orion-success)

Figure 14: An artist's impression of Artemis Astronauts working on the Moon *(Source: NASA)*

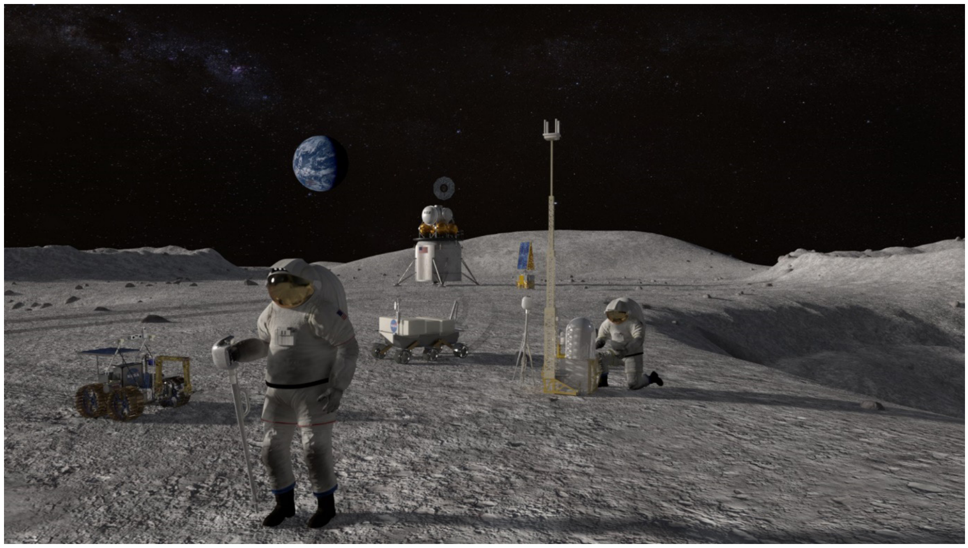


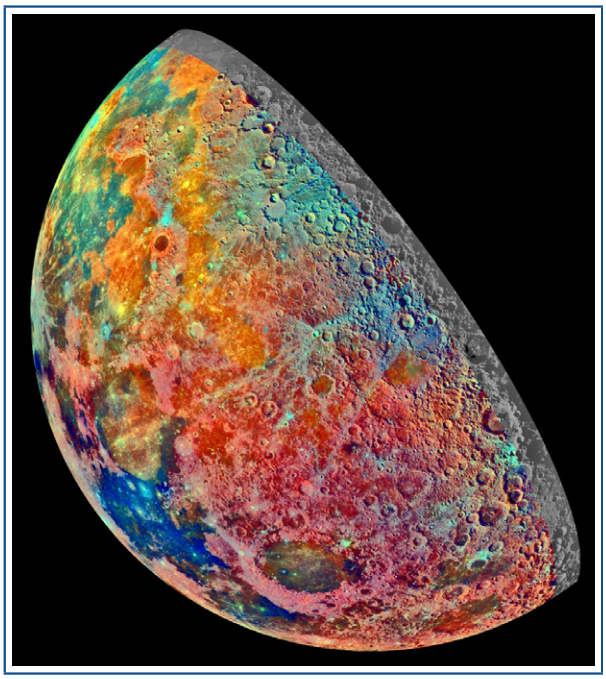
Table 1: Milestones of the Lunar Exploration Programme

Milestone	Year	Spacecraft	Country	Remarks
First flyby of the Moon	January 1959	Luna 1	USSR	Unintended; the spacecraft missed the Moon by 6000 km
First impact (hard landing) on the lunar surface	September 1959	Luna 2	USSR	East of Mare Serinitatis near Aristides, Archimedes and Autolycus craters
Imaging of the far side of the Moon for the first time	October 1959	Luna 3	USSR	Enabled first human glimpse of the far side of the Moon, which is invisible to Earth
First soft landing on the lunar surface	February 1966	Luna 9	USSR	Landing site was at Oceanus Procellarum west of Reiner and Marius craters
First artificial satellite of the Moon	April 1966	Luna 10	USSR	
First circumnavigation of the Moon by a crewed spacecraft	December 1968	Apollo 8	USA	Frank Borman, James Lovell and William Anders were the crew of Apollo 8
First Human Landing on the Moon	July 1969	Apollo 11	USA	Landing site was Sea of Tranquillity. Neil Armstrong, Edwin Aldrin and Michael Collins were the crew of Apollo 11. Neil Armstrong became the first human to step on the Moon (July 21, 1969 as per IST)
First robotic sample return mission	September 1970	Luna 16	USSR	Landing site was Northeast area of Sea of Fertility. The spacecraft brought back about 100 gm of lunar soil and rock samples
First rover on the moon	November 1970	Lunakhod 1	USSR	Landing and then roving site was in Sea of Rains
First soft landing on the far side of the Moon	January 2019	Chang'e 4	China	Landing and roving Site was in Von Karman crater, South Pole Aitken Basin of the Moon

Lunar Resources

Moon might become a source of many mineral and fuel resources which are essential for modern industrial civilization. Important elements like Aluminium, Titanium, Silicon, Iron, Calcium and Magnesium are abundantly found on the Moon[16, 17]. Besides, many of the rare earth metals, which are difficult to mine economically and in an environmentally friendly way on Earth, also exist on the lunar surface. Rare earths find use in manufacturing electronic devices and batteries for electric vehicles, which are now replacing fossil fuel burning vehicles[18,19].

Figure 15: An Artificially generated Lunar resource map using Galileo spacecraft data *(Source: NASA)*



Compared to Earth, Helium-3, an isotope of the element Helium, is found in relatively more abundantly on the Moon since it is deposited in large quantities on lunar surface by solar wind in an unhindered way due to the absence of lunar magnetic field. The presence of Earth's magnetic field prevents such deposition on Earth's surface. Helium-3 is very optimistically projected as a clean fuel for the fusion reactors, which, of course, are yet to be perfected. Helium-3 is not radioactive and its use in reactors would not produce harmful waste products[20].

Similarly, Oxygen, the single most abundant element on the Moon and bound in the lunar rocks, can be extracted through processes powered by electrical, thermal or chemical energy[21]. Additionally, water, which is essential for human survival, is also present in the lunar rocks and can be similarly extracted. In this context, it may be recalled that the pathbreaking discovery of its presence on the lunar surface was conclusively made by India's *Chandrayaan-1* spacecraft. Subjected to electrolysis, lunar water can yield Oxygen and Hydrogen which, through

16 Ian A Crawford, "Lunar Resources: A Review, Progress in Physical Geography", 39, (2015)

17 L Kesztehlyi, et al., "Resource Exploration and Assessments As Lunar Surface Science, Lunar Surface Science Workshop 2020" (LPI contribution no. 2241)

18 Renee, Cho "Rare Earth Metals: Will we have enough?", Columbia Climate School, September 19, 2012 (https://news.climate.columbia.edu/2012/09/19/rare-earth-metals-will-we-have-enough/)

19 Michael Sheetz, "Harvesting rare earth metals from the Moon will happen this century, NASA chief says", CNBC, July 18, 2019 (https://www.cnbc.com/2019/07/18/nasa-chief-bridenstine-on-harvesting-rare-earth-metals-from-the-moon.html)

20 European Space Agency, "Helium-3 mining on the lunar surface" (https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Space_for_Earth/Energy/Helium-3_mining_on_the_lunar_surface)

21 European Space Agency, "Team chosen to make first oxygen on the Moon", March 09, 2022 (https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Team_chosen_to_make_first_oxygen_on_the_Moon#:~:text=Samples%20returned%20from%20the%20lunar,is%20unavailable%20for%20immediate%20use.)

further processing, can be used as propellants in the rocket engines. Oxygen can also be used for breathing purpose by people living on the Moon thus enabling the sustainable human presence there[22].

Considering the tremendous cost involved in bringing the lunar materials back to Earth, utilisation of lunar resources on the Moon itself for building a manufacturing base is suggested[23].

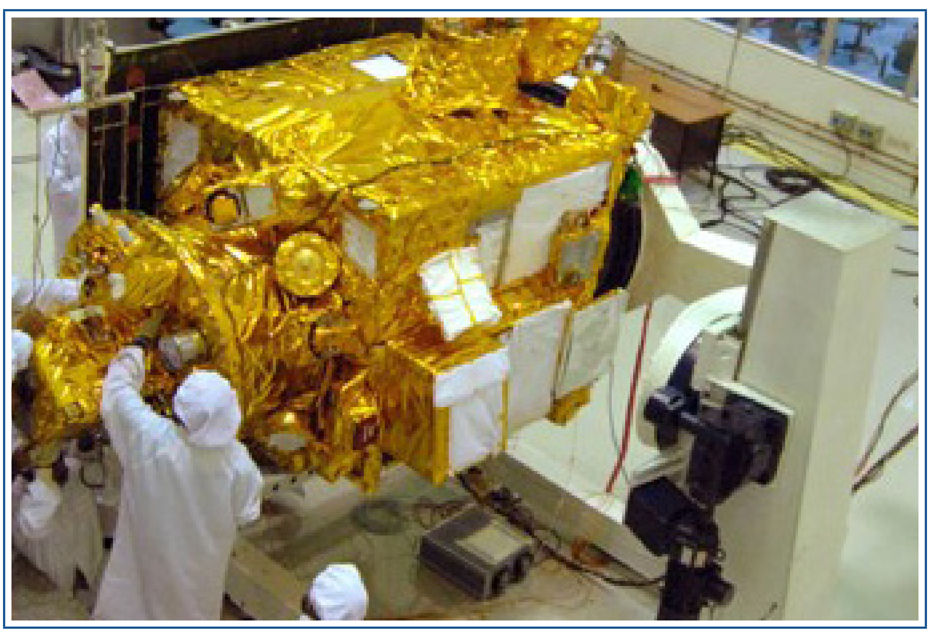
This apart, the top layers of the lunar soil (regolith) can be used as a shield for the first human habitats on the Moon from the harmful particles and electromagnetic radiations besides being utilised to make a concrete like substance as well as glass for building lunar habitats themselves[24].

Thus, Moon has plenty of essential resources which humanity can utilise. But utmost caution as well as regulation are essential in this regard to largely protect the pristine lunar environment and to ensure that they are accessible to the humanity at large and not to a select few countries. Against this background, a serious analysis of the various facets of the Artemis Accord and a decision on signing the same acquires added importance.

India's current capabilities

India has sent two robotic spacecraft missions to Moon – *Chandrayaan-1 and 2* – which have achieved varying degree of success. Through Chandrayaan-1, India demonstrated its ability to reach the surface of the Moon at a place and time of its choice. The country also successfully

Figure 16: Chandrayaan-1 Spacecraft undergoing pre-launch test *(Source: ISRO)*



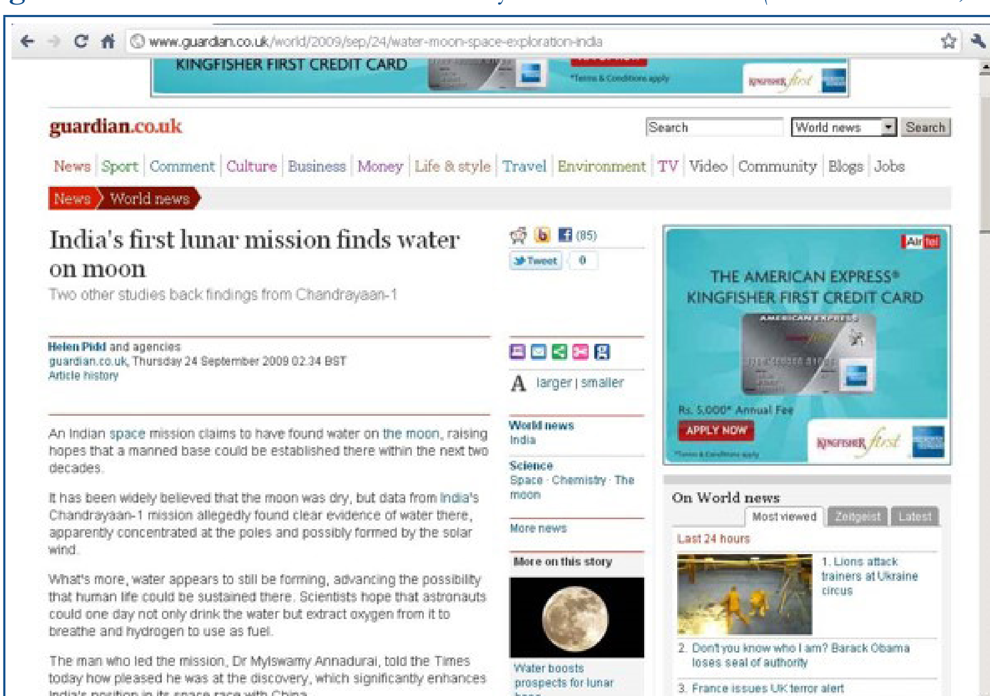
22 Sid Perkins, "The Moon may hold more water than we think, Science", 26 October 2020 (https://www.science.org/content/article/moon-may-hold-much-more-water-we-think)

23 "Mining the Moon", Mining Technology, December 4, 2017 (https://www.mining-technology.com/features/mining-the-moon/)

24 Robert L Reid, "Concrete mix for lunar applications is one step closer", Civil Engineering Scource, American Society of Civil Engineers (https://www.asce.org/publications-and-news/civil-engineering-source/civil-engineering-magazine/article/2022/08/concrete-mix-for-lunar-applications-is-one-step-closer)

Figure 17: Moon Impact Probe before its Integration with Chandrayaan-1 *(Source: ISRO)*

exercised the leadership role in that spacecraft mission with payloads from many countries including India. With the successful hitting of the lunar surface by the *Moon Impact Probe* on November 14, 2008 near the Shackleton crater in the lunar south polar region, India became the fourth individual country after the USSR, the United States and Japan (not counting Europe which is not an individual country) to reach the surface of the Moon. And, the conclusive



www.guardian.co.uk/world/2009/sep/24/water-moon-space-exploration-india

guardian.co.uk

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India's first lunar mission finds water on moon

Two other studies back findings from Chandrayaan-1

Helen Pidd and agencies
guardian.co.uk, Thursday 24 September 2009 02.34 BST
Article history

An Indian space mission claims to have found water on the moon, raising hopes that a manned base could be established there within the next two decades.

It has been widely believed that the moon was dry, but data from India's Chandrayaan-1 mission allegedly found clear evidence of water there, apparently concentrated at the poles and possibly formed by the solar wind.

What's more, water appears to still be forming, advancing the possibility that human life could be sustained there. Scientists hope that astronauts could one day not only drink the water but extract oxygen from it to breathe and hydrogen to use as fuel.

The man who led the mission, Dr Mylswamy Annadurai, told the Times today how pleased he was at the discovery, which significantly enhances India's position in its space race with China.

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Figure 18: Web News on India's discovery of Water on Moon *(Source: Guardian, UK)*

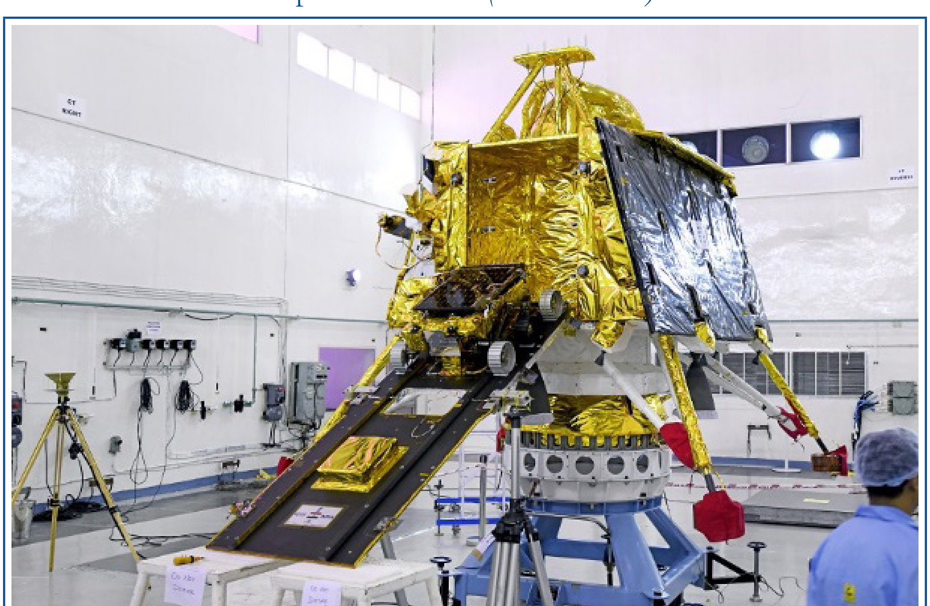
evidence of the presence of water on the lunar surface provided by *Chandrayaan-1* was hailed as a pathbreaking discovery.

Besides, the MiniSAR payload found more than 40 craters with the presence of subsurface water ice at their bottom. The two remote sensing cameras on *Chandrayaan-1* – Terrain Mapping Camera (TMC) and the Hyperspectral Imager – performed imaging of some portions of the lunar surface with the resolution of the panchromatic images from TMC being five metres. About 70,000 images of the Moon were collected before losing communications with the spacecraft on August 29, 2009. During its active life in orbit, *Chandrayaan-1* mapped six *Apollo* landing sites with one of the interesting images from *Chandrayaan-1* being the landing site of *Apollo 15* in the Hadley-Apennine region. The Lunar LASER ranging instrument of *Chandrayaan-1* enabled the generation of 3-D images of the lunar terrain. *Chandrayaan-1* also detected Iron, Calcium and Magnesium on the lunar surface.

Having acquired rich experience in studying the Moon from *Chandrayaan-1* through its imaging payloads, assessing the lunar terrain height through LASER ranging, exploring the elemental composition of it and unambiguously detecting water and water ice on the Moon, India graduated to *Chandrayaan-2* mission with the spacecraft equipped with an orbiter, lander and rover and the spacecraft launch weight increasing to 3840 kg, compared to 1380 kg for *Chandrayaan-1*.

Though the launch of *Chandrayaan-2* on July 22, 2019, subsequent navigation to Moon, lunar orbit insertion, orbiter lander separation and lander's orbit change to the one with a low perilune was flawless, the subsequent attempt to guide the *Vikram* lander carrying *Pragyaan* rover into a controlled descent gradually and smooth landing did not succeed as the communications with the spacecraft was lost during the final phase of landing when *Vikram* was at an altitude of about 2.1 km from the lunar surface. But the orbiter continued its assigned task of remote sensing the lunar surface and its exosphere and was

Figure 19: Pragyaan Rover, coming out on the ramp of Lander Vikram during a pre-launch test *(Source: ISRO)*



functional in March 2023, nearly four years after its launch. *Chandrayaan-3*, India's next mission to Moon, will feature only the lander and rover since Chandrayaan-2 orbiter is funcioning well. As Chandrayaan-3 lander can directly communicate with the Earth, it is planned to use *Chandrayaan-2* orbiter as back-up communications relay for the lander. Thus, *in situ* exploration of the lunar surface and the ambient conditions there are yet to be demonstrated by India through Chandrayaan-3 which is expected to be launched in July 2023.[25]

Of the eight indigenously developed payloads of *Chandrayaan-2* orbiter (as opposed to a combination of both Indian and foreign payloads of Chandrayaan-1), two are cameras, one a Radar instrument, two are X-ray instruments and one an infrared spectrometer. One of the two remaining instruments study particles rather than radiation and the remaining one studies radio waves[26].

Terrain Mapping Camera-2 (TMC-2) capable of facilitating high-resolution topographic maps and Digital Elevation Models (DEMs) of the lunar surface, has acquired images of different morphological features like craters, rilles and scarps on the lunar surface and helped in the generation of Digital Elevation Models and Ortho-images.

Orbiter High Resolution Camera (OHRC) has the capability to take highest resolution optical images ever (about 30 cm) from a lunar orbiter platform. This camera can also help study and select landing sites for future missions. OHRC has sent many images that conspicuously reveal the characteristics of different lunar surface features.

Imaging Infra-Red Spectrometer (IIRS) payload of *Chandrayaan-2* is capable of mapping minerals on the lunar surface. Its main focus is on extracting a clear signature of hydroxyl and/or water molecule on the surface of the Moon and it has demonstrated its ability to do so. This payload has been mapping the mineralogy of the Moon and sent valuable data in the past four years.

Dual frequency Synthetic Aperture Radar (DFSAR) is a radar instrument which does not rely on reflected sunlight. Instead, it sends out radio pulses towards the lunar surface and records the portion of those waves that were scattered from lunar surface. DFSAR is capable of measuring polarisation of scattered radio waves from permanently shadowed regions of the Moon. This instruments works in L-band observation of Moon and along with S-band, thus providing better identification of sub-surface water. This instrument has been imaging the lunar surface and the expectation is that it will provide new insights into the nature and distribution of lunar water-ice deposits.

Chandrayaan-2 Large Area Soft X-ray Spectrometer (CLASS) is one of the two X-ray payloads of *Chandrayaan-2*. It is capable of making the highest resolution surface composition study of the Moon using X- rays and thus comparatively better than similar payloads. This can lead to the generation of maps detailing the distribution of various elements over the entire lunar surface.

25 The Hindu Bureau, "Chandrayaan-3 spacecraft reaches launch port ahead of next month's launch", June 01, 2023 (https://www.thehindu.com/sci-tech/science/chandrayaan-3-spacecraft-reaches-launch-port-ahead-of-next-months-launch/article66919325.ece)

26 Indian Space Research Organisation, "Science Resurlts from Chandrayaan 2" (https://www.isro.gov.in/media_isro/pdf/ResourcesPdf/science_results_from_ch-2.pdf)

Additionally, it can help make monthly studies of geomagnetic tail at the Moon's distance. This instrument has unveiled new maps of different elements in detail. Apart from detecting elements like magnesium, aluminium, silicon, calcium, titanium and iron, CLASS has examined and detected two new elements – chromium and manganese for the first time.

The second X-ray payload of *Chandrayaan-2, called Solar X-ray Monitor (XSM)*, has the capability to observe the solar flare spectrum and its variation with time precisely. This is for supporting CLASS payload and for independent studies of the solar corona (Sun's outer atmosphere). This payload has observed several flares, including many low-intensity events called 'micro solar flares'. These observations, together with theoretical models, help researchers in understanding the evolution of physical properties of the Sun's Corona during solar flares.

Chandra's Atmospheric Composition Explorer–2 (CHACE-2) is included in Chandrayaan-2 for studying neutral atoms in the lunar exosphere (outer atmosphere) and their variation over different lunar areas as well as with time. This payload has detected signatures of Argon-40 isotope at 100 km altitude.

Dual Frequency Radio Science Experiment (DFRS) payload is intended for studying charged particles and neutral atoms near the Moon using the radio occultation technique.

Possessing these indigenously built instruments, *Chandrayaan-2* is studying several facets of the Moon from its 100 km high lunar polar orbit. Thus, India has demonstrated its capability to launch a 4-ton class lunar robotic spacecraft, its accurate navigation to moon, impacting a small probe to lunar surface over a particular area and at an assigned time of its choice, remotely sensing the lunar surface and exosphere from lunar orbit, simultaneous operations of lunar orbiter and lander in orbit and achieving a low perilune orbit around the Moon for its lander and initiating the soft-landing sequence. Therfore, India's current capability to explore the Moon through its lunar orbiting robotic spacecraft is repeatedly well demonstrated.

International Lunar Missions – Status and Outlook for India

Rajaram Nagappa*

Introduction:

Beginning 2018, there is a renewal of interest in the exploration of the moon. Many of the missions are geared towards understanding and characterizing the lunar environment but there is an underlying embedded commercial interest factor. In this, one discerns the beginning of a race led by USA on the one hand and the Chinese-Russian collaboration on the other. All said and done, the calendar for both robotic and human missions is laid out till 2028[27]. There could be some slippages from the planned schedule, mainly due to technology reasons but there appears no letup in the pursuit of lunar goals. The US, ESA, China and Russia are prominent players; India, Japan, South Korea and Israel have planned missions; and some private enterprises also have a stake.

The successful maiden flight of NASA's Space Launch System (SLS), the near flight readiness of SpaceX Starship, and CNSA's Long March 5 will be important components of Earth-moon transportation system. ISRO's LVM-3 and JAXA's H-3 are other candidate systems. An assessment of the technology gains from the missions and their technology spinoffs merits consideration to see where India is placed.

Current and Planned Lunar Missions

In this section, lunar missions completed and planned from the year 2018 will be briefly described.

1. Year 2018-2019

1.1. Chang'e 4 Mission: This was a remarkable mission of CNSA, China. The Mission accomplished the first ever soft landing on the far side of the moon in the Von Karman Crater on January 03, 2019. To facilitate communication with the satellite on the far side of the moon, the Queqiao relay satellite had been placed in a halo orbit around the second Earth-moon Lagrange Point in June 2018. The Lander deployed the Yutu-2 rover to survey the lunar surface.

Chang'e4 has a mass of 425 kg and its 4.2m dish antenna receives communication from the lander and Yutu Rover in X band and relay to the earth station is in S band[28].

1.2. Chandrayaan-2 Mission: India's second mission to the moon was launched on July 22, 2019. The ambitious mission involved achieving lunar orbit, separation of the

* Honorary Visiting Professor, ISSSP, National Institute of Advanced Studies, Bengaluru.

27 European Space Agency. (accessed 2023, March 20). *Planned Future Missions.* https://lunarexploration.esa.int/explore/esa/234

28 Op cit. 27

Vikram Lander and its soft landing on the lunar soil and deployment of Pragyan Rover. The Orbiter weighing 2379 kg was successfully inserted into 100 km lunar polar orbit on August 20, 2019. Unfortunately, soft landing of Vikram and Pragyan could not be achieved[29].

The orbiter has an estimated life of 7 years and the eight payloads on board continue to function. The orbiter has a high-resolution camera to provide 0.3m resolution images and the onboard payloads will be useful for mapping of minerals and water molecules in the lunar polar regions.

1.3. Beresheet: This was Israel's maiden attempt to put a robotic lander on the moon. Beresheet was launched aboard Space X Falcon 9 rocket and inserted itself into lunar orbit on April 04, 2019. Soft-landing of Beresheet in the Sea of Serenity area on April 11, 2019 was not successful resulting in its crashlanding. Beresheet weighed 585 kg and measured 1.5 m (height) by 2.3 m (width) with its legs deployed[30].

2. Year 2020

2.1. Chang'e 5: Launched on November 23, 2020, Chang'e 5 represents China's sample collection and return mission[31]. The major elements of the spacecraft are a) service module, b) lander, c) ascent vehicle and d) Earth return module. The mission design allows descent of the lander and ascent module to the lunar surface while the other two elements remain in lunar orbit. The Lander uses a drill to penetrate 2m into the ground and a mechanical scoop is used to collect the sample. Sample retrieval and return follows a sequence in which, the Ascent Vehicle blasts off from the lunar surface, rendezvouses with the Service Module and transfers the sample to the Earth Return Vehicle. The service module jettisons the Ascent Vehicle, sets itself on an Earth-bound trajectory and releases the Earth Return Capsule at the appropriate time. In this mission, moon landing was achieved on December 01, 2020 and return to Earth with 1.73 kg of lunar sample was achieved on December 16, 2020. The capsule return and recovery had been rehearsed in the 2014 Chang'e 5 TI mission.

3. Year 2021: No Missions

4. Year 2022:

4.1. Artemis 1 Mission: On November 16, 2022, launch of USA's new Space Launch System (SLS) Rocket with Orion spacecraft as the main payload signaled the return of the human flights to the moon. Artemis 1, an uncrewed flight was the first of a series of flights which will enable stay and exploration of the moon. After the main stage burn and insertion into Earth orbit, the Interim Cryogenic Propulsion Stage (ICPS) fired and sent Orion spacecraft into lunar trajectory. Subsequent propulsion was provided by ESA's European Service Module which enabled Orion to reach the Moon on the

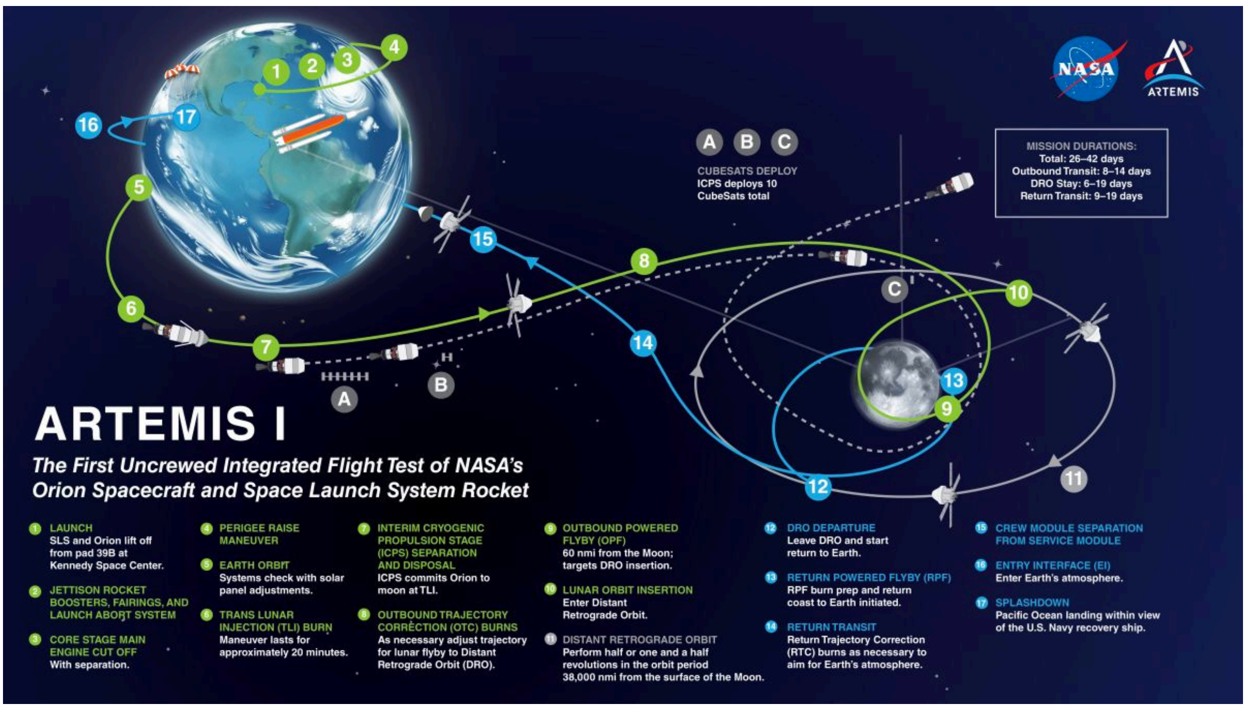
29 Indian Space Research Organization. (accessed 2023, March 20). *Chandrayaan 2*. https://www.isro.gov.in/Launcher.html

30 NASA Solar System Exploration. (accessed 2023, March 20). *Beresheet*. https://solarsystem.nasa.gov/missions/beresheet/in-depth/

31 The Planetary Society. (accessed 2023, March 22). *Chang'e-5: China's Moon Sample Return Mission*. https://www.planetary.org/space-missions/change-5

6th day and entered a deep retrograde orbit (about 70000 km) and stayed in orbit for 6 days. On December 01, the Orion capsule began its earthward journey landing off the coast of Mexico's Baja Peninsula on December 11[32]. The 2.3 million km journey from launch to splashdown of Artemis 1 is reproduced in figure 20.

Figure-20: Artemis 1 Mission *(Source: NASA)*



In this mission, ten CubeSats, which had piggybacked in the flight were deployed after ICPS firing. The CubeSats and their main functions are described below[33]:

- Lunar IceCube: Weighing 14 kg, Lunar IceCube does one hour of observation in its 7-hour orbit around the moon. Its main instrument Broadband InfraRed Compact High Resolution Exploration Spectrometer (BIRCHES) is able to sniff out presence of water across the moon.

- LunaH-Map: The Lunar Hydrogen Mapper will be operative for 60 days and will map the hydrogen content of the lunar south pole – both on the surface and one meter below the surface – using a neutron detector.

- LunIR: LunIR will image the lunar surface and characterize it for prospecting potential landing sites for future missions.

- OMOTENASHI: Outstanding Moon

32 Space.com. (2022. December 12). *Artemis 1: The first step in returning astronauts to the moon*. https://www.space.com/artemis-1-going-back-to-the-moon#section-artemis-1-s-flight-to-the-moon

33 Space.com. (2022. August 26). *Artemis 1 cubesats: The 10 tiny satellites hitching a NASA ride to the moon*. https://www.space.com/nasa-artemis-1-moon-mission-cubesats#section-the-cubesats-and-their-missions

Exploration Technologies demonstrated by Nano Semi-Hard Impactor weighing 12.6 kg in 6U construction will deploy a nanolander soft landing on the moon to measure surface radiation and carry out soil mechanics studies.

- BIOSENTINEL: The 3U cubesat weighing 13 kg represents an astrobiology mission to understand the effect of radiation on living organisms in space. Yeast is used as the model organism for this study.

- ArgoMoon: This ESA 6U cubesat is meant to send images of launch vehicle performance. ArgoMoon after separation from ICPS will monitor ICPS performance with regard to separation of other cubesat payloads.

- In addition, Artemis 1 mission will carry four other cubesat payloads with non-lunar primary missions. NEA Scout relates to flyby mission to an asteroid; EQUULEUS will observe earth's plasmosphere from an orbit between Earth and moon; CuSP will study solar events; and Team Miles will be on a trajectory to Mars using a Plasma Iodine thruster. Each of these will add value to future human deep space missions.

4.2. Danuri: Previously known as Korea Pathfinder Lunar Orbiter (KPLO) is South Korea's first foray into lunar exploration[34]. Danuri was launched aboard Space X on August 04, 2022 with the objective of a) demonstrating key technologies and b) carry out scientific studies of lunar environment including topographic lunar map. The 678 kg Danuri with its six payloads will have a mission life of one year[35]. Its findings will also be used by NASA Artemis Program.

5. Year 2023

5.1. Hakuto R Mission 1: Private Japanese company ispace chalked a landmark event entering lunar orbit on March 21, 2023. The spacecraft carried a lander measuring 2.3 m height and 2.6 m across with a dry mass of 340 kg. The lander can house 30 kg mass payloads. Soft landing of the lander on lunar surface attempted on 25 April 2023 was not successful. The company intends to rectify the problem and repeat the mission. In the long run, the company will offer lunar orbit and lunar surface services on a commercial basis[36].

5.2. Peregrine Mission 1: Peregrine Lander is designed to put payloads into lunar orbit and land payloads on moon[37]. The mission plan is to touch down on lunar surface Sinus Viscositatis and the mission objectives include study of lunar exosphere, study of hydrogen abundance in the lunar regolith, magnetic fields and radiation environment. The maiden mission originally planned for 04 May 2023 is delayed due to launch

34 Korea Aerospace Research Institute. (accessed 2023. March 22). *Korea's first step towards lunar exploration*. https://www.kari.re.kr/eng/sub03_07_01.do

35 Space.com. (2023. January 04). *Danuri: Facts about the Korea Pathfinder Lunar Orbiter (KPLO).* https://www.space.com/danuri-korea-pathfinder-lunar-orbiter-kplo-moon-mission

36 Ispace. (accessed 2023. March 24). *Hakuto-R Mission 1*. https://ispace-inc.com/m1

37 NASA. (2023. March 28). *Peregrine Mission 1 (T02 AB).* https://nssdc.gsfc.nasa.gov/nmc/spacecraft/display.action?id=PEREGRN-1#:~:text=Description,is%20designated%20Peregrine%20Mission%201.

vehicle related issues. The Mission will host 14 payloads and the payload mass on the lander will be 90 kg. The Lander built by Astrobotics is about 1.9 m high and 2.5 m across in width. Propulsion is by means of 667 N bipropellant thruster.

5.3. Chandrayaan 3: This is a follow-on mission to Chandrayaan 2 and is expected to be launched by June-July 2023. Like the previous mission, the complement of Lander and Rover will be launched from the Propulsion Module from a 100 km lunar orbit[38]. The objectives of the Mission are to demonstrate a) safe and soft landing on lunar surface, b) roving operations by the Rover and c) conduct of in-situ scientific experiments. To meet the mission objectives, the Lander includes advanced technologies and sensors; and both Lander and Rover carry a number of scientific payloads. The Lander and Rover together weigh 1778 kg and the prime landing site is an area of 4 km x 2.4 km located at 69.37S, 32.35E[39].

5.4. Luna 25: Also known as Luna-Glob is Russia's rekindled interest in lunar missions after a long gap. Its predecessor Luna 24 was launched in 1976. The 800 kg Luna 25 is scheduled to be launched on board Soyuz-Fregat vehicle on July 13, 2023. Like other lunar missions, south polar region is the area of exploration for Luna 25 with the scientific objectives of a) study of composition of lunar regolith and b) study of plasma and dust components of the lunar polar exosphere[40]. ESA is planning to fly a Pilot D demonstrator camera as part of the mission. The landing site chosen for Luna 25 is at 69.55S, 43.54E, north of the Boguslavsky crater with an alternate site near the Manzini crater.

5.5. SLIM: This JAXA Mission is a technology demonstrator of accurate lunar landing technique using a small and smart lander[41]. Techniques developed through the Smart Lander for Investigating Moon (SLIM) will be a demonstration for future lunar sample return missions. SLIM weighing 190 kg is 2.4 m tall and measures 2.7 m x 1.7 m across. It is expected to be launched in late 2023.

5.6. Space X-Starship: It is likely that Space X may do a space tourism trip around the moon in late 2023. Japanese billionaire Yusaku Maezawa with eight other select passengers will be on board the planned 8-day mission. The mission will take place subject to clearance by the US authorities[42].

6. 2024 and Beyond:

Nearly a dozen lunar missions are planned in 2024 and the subsequent years. Only the significant of these are detailed below:

38 Huma Siddiqui, (2023, March 17). Chandrayaan-3 launch in June-July 2023 will explore the "Dark Side of the Moon". *Financial Express*. https://www.financialexpress.com/defence/chandrayaan-3-launch-in-june-july-23-will-explore-the-dark-side-of-the-moon/3013693/

39 ISRO. (accessed 2023. March 25). *Chandrayaan 3*. https://www.isro.gov.in/Chandrayaan3_New.html

40 NASA. (2023, March 28). *Luna 25*. https://nssdc.gsfc.nasa.gov/nmc/spacecraft/display.action?id=LUNA-25

41 NASA. (2023, March 28). *Smart Lander for Investigating Moon (SLIM)*. https://nssdc.gsfc.nasa.gov/nmc/spacecraft/display.action?id=SLIM#:~:text=The%20Smart%20Lander%20for%20Investigating,planets%20using%20lighter%20exploration%20systems.

42 BBC News. (2022. December 24). *The countries launching missions to the Moon and beyond in 2023*. https://www.bbc.com/news/science-environment-64002977

6.1. Artemis Missions[43]: Artemis 2 will be the first crewed flight around the moon and back. The mission lasting 8-10 days plans to take the Orion crew module 7400 km beyond the far side of the moon to complete a flyby and return to earth. Artemis 3 will also be a crewed mission in which the 4-person crew will dock with the Lunar Gateway and remain in orbit for 30 days. Two of the astronauts will use the human landing system to land at the Lunar south pole region to explore and carry out scientific experiments. Artemis 3 will be the total platform for testing all elements (Orbiting Lunar Station, Human Landing System and Rover) of the mission. According to the Canadian Space Agency, the mission will "aim to hit four major metrics of readiness, viz., mission planning, system performance, crew interfaces and guidance and navigation systems"[44].

Artemis 2 mission is planned for late 2024. Planning and realization of further missions is underway. Mission scheduling will take into account performance and analysis of all the systems of the Artemis 1 and 2 Missions as well as specific requirements of the planned future missions.

6.2. Chang'e: China has planned a well thought out and elaborate approach to lunar exploration through its Chang'e 6-8 Missions[45].

Chang'e 6 planned for launch in 2024 or 2025 will be a sample return mission. About 2000 grams of lunar sample from the far side of the moon will be collected for return to Earth. The landing site will be on the far side South Pole Aitken Basin and Queqiao 2 Relay satellite will be launched in early 2024 for communication with Chang'e 6.

Chang'e 7 planned for 2026 will carry Orbiter, Lander, Rover and Probe for detailed investigation of the lunar south polar region. The favorable solar illumination condition as well as relatively stable temperatures will be helpful in conducting long term robotic exploration. Detection of water ice in the permanently shadowed region will be a primary objective. Other objectives include terrain, geology and space environment.

Chang'e 8 may be launched sometime in 2028. Its mission will be to test out technologies required for establishing a lunar science base. Chang'e 7 and Chang'e 8 will provide information for the basic structure of the planned International Lunar Research Station (ILRS).

6.3. Lunar Polar Explorer (LUPEX): LUPEX is a Japan-India collaboration to explore the lunar south polar region[46]. India's contribution will include the lander, while Japan will provide the rover and launch

43 Royal Museums Greenwich. (accessed 2023. March 25). *Follow the NASA Artemis Missions*. https://www.rmg.co.uk/stories/topics/nasa-moon-mission-artemis-program-launch-date#Future%20Artemis%20missions

44 Space.com (2022. November 16). *Artemis 2 mission: Taking humans around the moon*. https://www.space.com/artemis-2-humans-moon-orbit

45 Deng Xiaoxi. (2023, February 06). Chief Designer discloses China's Phase-4 lunar probe plans. *Global Times*. https://www.globaltimes.cn/page/202302/1284935.shtml

46 WION. (2021, November 05). *Indian lunar lander, Japanese Rover to explore Moon in LUPEX Mission, says JAXA official*. https://www.wionews.com/india-news/indian-lunar-lander-japanese-rover-to-explore-moon-in-lupex-mission-says-jaxa-official-431774

on board the H3 rocket. The principal objective is to study the presence of water ice (quantity, quality and usability) by direct measurement on the lunar surface. The Mission was originally planned during 2023-24 but is likely to be delayed on account of issues with H3 launch vehicle and the inputs from Chandrayaan 3 mission.

6.4. Luna 26-29: As part of the Luna-Glob program, Russia has plans to carry out lunar orbit, sample return and robotic survey of the lunar surface over the coming years[47].

Luna 26, a lunar orbiter is also known as Luna-Resurs. Besides carrying out a host of scientific studies with 14 instrumented payloads, Luna 26 will also function as a telecommunication relay station between Earth and Russian landed assets on the moon. There is collaboration with ESA in relation to communication, precision landing, hazard avoidance, sample drilling and sample return. The main objectives of the Luna spacecraft are as follows:

- Luna 26: Orbital mission involving scientific exploration, survey of potential landing sites for Luna 27
- Luna 27: Lander mission with the aim of collecting and studying lunar sample composition.
- Luna 28: Samples return mission and will also be a demonstrator for future Martian samples return mission.
- Luna 29: will land a heavy rover on the lunar surface

Some of the Luna missions envisage cooperation with ESA and there could be US supplied components and subsystems. Luna 26 is set for launch in 2024 and the launch schedule of the remaining satellites is not yet known. Their launch schedule could be affected on account of the Ukraine conflict and the sanctions Russia is facing.

6.5. Other Missions: There are other missions planned to be undertaken, which will add value to lunar exploration.

- Volatiles Investigating Polar Exploration Rover (VIPER): This mobile robot is expected to land at the Lunar South Pole in late 2024 on a 100-day exploration mission seeking information on the origin and distribution of water on the moon. It will provide pointers as to how to harvest the lunar resources for future human space exploration[48].
- In-situ Resource Utilization (ISRU): This is a demonstration mission of ESA planned for 2025. The aim of the mission is to demonstrate the feasibility of water or hydrogen production on the moon. Mission enabling services like payload delivery, communication and operations are planned to be procured from commercial sector.
- European Large Logistics Lander (EL3): The 8500 kg Lander is proposed to be launched on Ariane 64 sometime in 2027-28. The EL3 will complement the Artemis Program with its capability to bring food and other stores as well as equipment for a crew of four working

47 Next Spaceflight. (accessed 2023, March 25). *Status Luna 26*. https://nextspaceflight.com/launches/details/1374

48 NASA. (accessed 2023, March 25). *Viper Mission Overview*. https://www.nasa.gov/viper/overview

on the moon. The Lander will also be the survival platform for lunar explorers[49].

Analysis and Discussion:

From the foregoing description, the following inferences can be drawn.

1. The motivation to explore the moon is strong and many space entities– both government and private – have carried out or are planning lunar missions.

2. The current and planned missions seem to be aimed at getting a measure of a) the lunar resources, b) requirements for habitation, c) requirements of communication, d) safety of operations and e) requirements for in situ processing/utilization. While exploration and knowledge gain are the primary goals, one can discern a specter of a race among competing parties.
3. Most landings and explorations are in the vicinity of the lunar south pole – an area in permanent shadow with the promise of water ice reserves.

4. Moon is strewn with millions of glass beads formed over billions of years. Examination of the soil sample returned from Chang'e 5 mission confirm that these beads hold significant amounts of water. Researchers estimate that up to $270x10^{12}$ kg of water could trapped in the top 12 m of the lunar surface[50].

5. Some missions including miniature landers are based on CubeSats. Opportunities exist for many application missions using CubeSats and other miniature satellites.

6. USA, China and Russia have long term plans

7. Table 2 below provides a summary outline of lunar missions

Table 2: Summary of Lunar Missions

Country/ Year	Mission	Orbiter	Lander	Rover	Remarks
China/2019	Chang'e 4	--	✓	✓	Soft landing on far side of moon. Queqiao relay satellite at Lagrange Point
India/2019	Chandrayaan 2	✓	--	--	Soft landing of lander+rover could not be achieved
Israel/2019	Beresheet	--	--	--	Soft landing failure
China/2020	Chang'e 5	✓	✓	--	Sample collection & return
USA/2022	Artemis 1	--	--	--	Uncrewed. 6-day orbit around moon & return
ROK/2022	Danuri	✓	--	--	One year life. Findings will feed to Artemis mission
USA/2023	Peregrine 1	✓	✓	--	Astrobotic, a private company will provide lunar orbit/lander services

49 European Space Agency. (accessed 2023, March 25). *Argonaut – European Large Logistics Lander.* https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Exploration/Argonaut_European_Large_Logistics_Lander

50 Space.com. (2023, March 29). Hidden water source on the moon found locked in glass beads, Chinese probe reveals. https://www.space.com/moon-water-glass-beads-change-5-reveals

Country/ Year	Mission	Orbiter	Lander	Rover	Remarks
India/2023	Chandrayaan 3	✓	✓	✓	Follow on mission of Chandrayaan 2
Russia/2023	Luna 25	--	✓	--	Land near south pole. ESA Pilot D camera will be used to image the terrain
Japan/2023	SLIM	--	✓	--	Technology demo for accurate landing using small and smart lander
USA/2024	Artemis 2	--	--	--	Crewed mission. Orbit around moon and return
China/2024	Chang'e 6	✓	✓	--	Land on far side of moon. Sample collection & return
India-Japan/ 2024	LUPEX	--	✓	✓	Polar water study – quantity, quality, usability
Russia/2024	Luna 26	✓	--	--	Survey from orbit
USA/2025	Artemis 3	✓	✓	✓	Crewed landing, stay up to 8 days
Russia/2025	Luna 27	--	✓	--	Sample collection & analysis. ESA supplying drilling/sampling tools
China/2026	Chang'e 7	✓	✓	✓	Lunar exploration
ESA/2027	ISRU	--	✓	--	In situ resource utilization experiments. Commercial sector to provide mission related services
Russia/2027	Luna 28	✓	✓	✓	Sample collection & return
China/2028	Chang'e 8	✓	✓	✓	Test technologies relevant to Lunar Science Base
ESA/2028	EL3		✓	✓	Delivery of scientific or logistic payload to lunar surface

8. It is apparent from the table contents that Artemis mission has a well laid out long-term plan for crewed missions to the moon; plans for habitat creation; surveying, prospecting and mining resources on the moon; processing the resources for habitation purpose, missions beyond moon and commercial purposes. US plans to do this both on its own as well as in partnership with other Artemis Accords partners.

9. It is also clear that next to the US, China has elaborate plans and would be working on establishing its own lunar base beyond Chang'e 8 mission in 2028. While Russia is a known partner in the Sino-Russian led International Lunar Research Station. It is possible, that some members of the Asia Pacific Space Cooperation Organization (APSCO) may also be roped in.

10. Russia, which was an important space player prior to the breakup of Soviet Union has lagged behind the US, EU and China. However, it has the technical potential and aims to make up for lost ground through its Luna missions. Its ability to stick to the planned schedule is questionable on account of financial and prevailing geopolitical situation. Nevertheless, between China and Russia, there is significant technological capability.

11. India, Japan and South Korea are other nations with capability and plans for furthering their interests in the moon. ESA

has also abiding interest and plans to be part of lunar exploration.

12. Importantly, startups and private firms are ready to provide orbiter/lander/rover services.

13. It would appear that studies relating to lunar resources, terrain, and landing site selection will take priority. Robotic lander and rover services will be mostly employed.

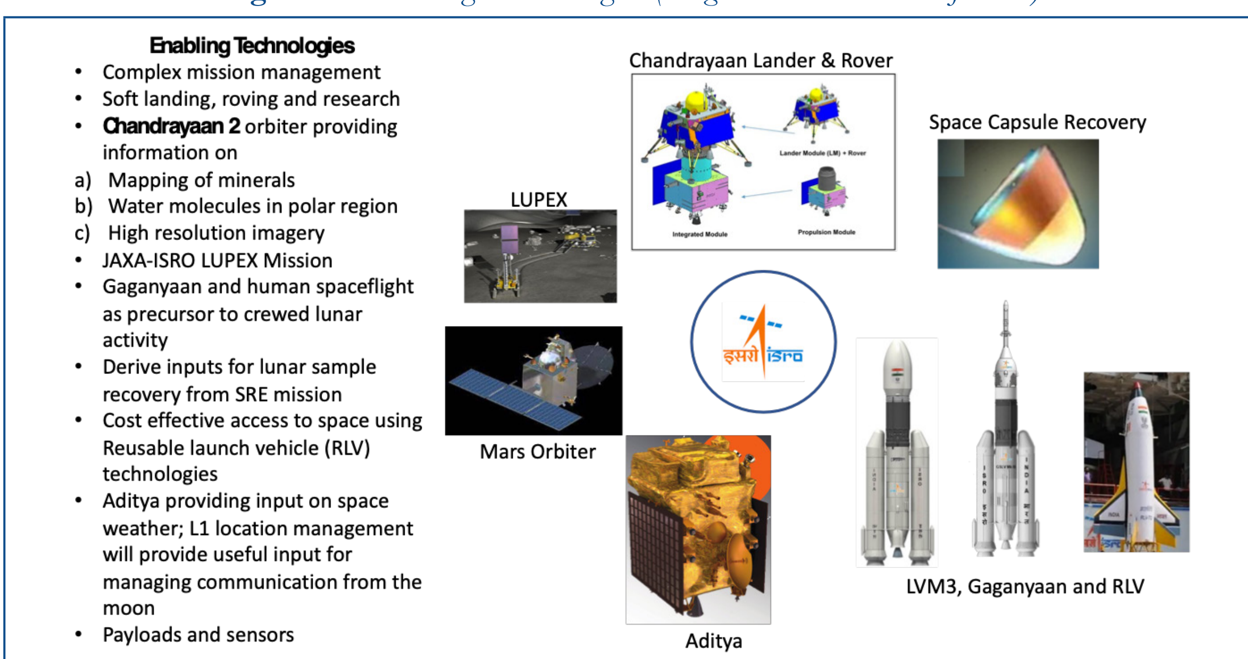
14. Safety and reliability are prime concerns for crewed missions. Consequently, detailed analysis of results from flight of uncrewed prototypes as well as incorporation of modifications/corrections if required as well as emergency crew rescue services will have to be in place before crewed missions are undertaken.

15. This consolidation can happen by 2030 and it can be expected that lunar habitation and lunar resource utilization will come into focus in the next decade. US led Artemis Mission and China led ILRS would be playing lead roles.

India – Next Steps

India has not made public its long-term lunar mission plans. However, ISRO is putting into place missions, which can be seen to serve as building blocks for lunar and other deep space missions. India possesses rich experience in designing and implementing diverse missions; as also placing satellites in desired individual or multiple orbits; managing the spacecraft during its lifetime; in designing payloads and sensors. This capability enables India to harness this knowledge and develop afresh technological requirements needed for future lunar missions. Further, India is in a position to carry out the mission tasks either individually or collaboratively with other potential partners. Figure 21 indicates some of the enabling technologies developed by ISRO which can be used or adapted for future lunar and deep space missions.

Figure 21: Enabling Technologies *(Images Source: ISRO and JAXA)*



From figure 21, it can be surmised that India has developed capability to launch sophisticated payloads and manage the flight to lunar orbit; improvements in future may be able to launch heavier payloads at lower cost using reusable launch vehicle technology; Chandrayaan 2 Orbiter continues to provide information and data useful for new missions; soft landing of Lander and Rover of Chandrayaan 3 will enhance lunar exploration capability; LUPEX Mission jointly planned with JAXA will use ISRO Lander and JAXA Rover and will enhance exploration of the lunar polar regions; Gaganyaan 1 will provide useful inputs for undertaking crewed missions to the moon. It is, therefore, evident that India has developed and is developing capabilities and will be in a position to undertake individual missions or contribute positively to joint collaborative missions.

ISRO has not made public its plans after Chandrayaan 3 and one assumes, besides the LUPEX Mission, ISRO may also plan a sample retrieval and return mission. Startups may provide independent orbiter/lander services as well as develop technologies for sample collection, habitat material and process and ISRU. The apex need and requirement will be a crewed ISRO mission to the moon, which could perhaps be possible by the end of the decade.

Conclusion

India has a mature space program and its application programs have benefitted the country's development and societal goals as well as cater to some dual-purpose requirements. Indian space has now embarked on human space flight, development of heavy lift and reusable launch vehicles and also spread its activities beyond Earth orbit. Recent reforms in the space sector have encouraged private sector participation and this move has already borne fruit with established firms as well as startups linking themselves to space business opportunities. India also has a good record of international cooperation in space related matters. In the past, while India has been good at developing technology, it has been hampered by lack of capacity. This can now be overcome to quite some extent with private sector participation. For example, for lunar missions, India can provide orbiter, lander and rover services similar to Hakuto/SLIM/Peregrine/LUPEX missions. It can be recalled Team Indus, was one of the five finalists in the Google Lunar X competition with similar mission aims.

Overall, India is well equipped to contribute to space missions in both Earth and beyond Earth domains. India is poised to be an active player by virtue of its demonstrated capabilities and the further planned missions. India will be in a position to build on its capabilities, contribute to the overall information and knowledge generation and accelerate the development of its mission as a partner in the NASA Artemis Program.

China's Moon Exploration Plans

Amit Mukherjee*

Introduction

China's space vision was outlined by the Chinese President in 2021 as "(To) explore the vast cosmos, develop the space industry and build China into a space power is our eternal dream"[51]. The vision document further elaborates as "to explore outer space to expand humanity's understanding of the earth and the cosmos; to facilitate global consensus on our shared responsibility in utilizing outer space for peaceful purposes and safeguarding its security for the benefit of all humanity". It is further elaborated that the primary aim of China is to secure economic, scientific and technological advancement and in the process address issues of national security and social progress; to raise the scientific and cultural levels of the Chinese people; protect China's national rights and interests; and build up its overall strength[52]. Among the major steps that China is taking to stamp its space leadership is through advancing lunar research – more specifically, by establishing a lunar base. The International Lunar Research Station (ILRS), according to Chinese Space Agency "ILRS is a complex of experimental research facilities to be constructed with possible attraction of partners on the surface and/or in the orbit of the Moon designed for multi-discipline and multi-purpose scientific research activities, including exploration and use of moon, moon based observation, fundamental research experiments and technological verification, with the capability of long term unmanned operation with the prospect of subsequent human presence"[53].

China has a good record of international cooperation and it remains to be seen whether the cooperation will continue in lunar research. Since 2016, China has signed 46 space cooperation agreements or memoranda of understanding with 19 countries and four international organizations. Among international partners, it has cooperation with Russia, European Space Agency, Sweden, Germany, the Netherlands and Saudi Arabia: In *Tianwen 1,* China's first mars exploration mission, China cooperated with France. China has also carried out gamma-ray burst polarization monitoring research with the European Space Agency on the Tiangong-2 space station and conducted human system related medical research in a micro-gravity environment with France during the Shenzhou-11 manned spaceflight mission.[54] In other missions, it has also cooperated with the Space agencies of Namibia, Argentina, and Pakistan, at some level. In the Chang`e 7 mission for lunar polar

* Assistant Professor, ISSSP, National Institute of Advanced Studies, Bengaluru.

51 Xinhua, China's Space Program: A 2021 State Council PRC, Jan 28, 2023.

52 Ibid, 2023

53 Op. cit. 2,3.

54 http://english.scio.gov.cn/whitepapers/2022-01/28/content_78016877_7.htm

exploration, China is collaborating with Russia for its LUNA Resource 1 orbiter[55].

In keeping with its space ambitions and related moon missions, the Chang`e series of spacecraft were launched with the first being in 2007. The Chang`e series envisioned a permanent station on the moon and was supposed to run in four stages, three of which have been completed, including, Orbital missions, Soft landers/rovers, Sample-return, and a Lunar robotic research station. Functions included making outline and landform maps, detecting chemical elements along with their distribution, measuring the lunar depth, and examining the space weather between the moon and the earth's surface[56]. The series of Chang`e spacecraft missions that have flown so far since 2007 includes Chang`e 2 in 2010 for moon mapping, Chang`e 3 in 2013 with a rover payload Yutu[57], Chang`e 4 in 2019 with a second rover Yutu 2, Chang`e 5 in 2020 which brought back lunar soil samples. The future missions of the Chang`e series include Chang`e 6 in 2024 for subsurface readings, Chang`e 7 in 2026 for the exploration of resources, Chang`e 8 in 2028 for installing an experimental habitat, and China hopes to set up a fully operational moon base by 2035[58].

Geopolitical backdrop to ILRS

The race to set up a moon base has its precedents in history popularly known as the cold war era space race. The Kennedy administration found the moon as the best challenge and position to establish US superiority. For the succeeding two decades, competing lines for domination of the space race became a paramount policy directive for both superpowers of the time[59].

In the past, complex international situation also led to healthy cooperation. Apollo-Soyuz joint mission is an example of the same. In recent times, similar cooperation has ensured safe functioning of the International Space Station inspite of the Ukraine conflict. This cooperation may come to an end as Russia has decided to pull out of the ISS partnership in 2024[60].

China's manned space programme on the other hand, has gained momentum since the first crewed flight in 2003. China is also building its own large space station and the Tianhe core module of the Tiangong space station was launched in 2021[61]. In 2022 October, China completed the docking of the third module for the T shaped structure of the station. It can be seen that China has a well-articulated programme

55 Adam Mann, China's Chang'e Program: Missions to the Moon, space.com, 2019.

56 Chang`e 1 Lunar 1 Mission of China, 2012, eoPortal, https://www.eoportal.org/satellite-missions/chang-e-1#Chang`e---1-lunar-1-mission-of-china

57 Chang'e-4 and Yutu-2, China's mission to the Moon's farside, https://www.planetary.org/space-missions/Chang`e-4

58 SCIO briefing on white paper 'China's Space Program: A 2021 Perspective', 2022, CNSA, cnsa.gov.cn, http://www.cnsa.gov.cn/english/n6465652/n6465653/c6813196/content.html, accessed on 12 March 2022.

59 Maddie Davis, The Space Race, Soviets Americans Race to the Stars, Miller Center, https://millercenter.org/the-presidency/educational-resources/space-race

60 "Russia to quit International Space Station after 2024", The Economic Times, July 27, 2022, https://economictimes.indiatimes.com/news/international/world-news/russia-to-quit-international-space-station-after-2024-official/articleshow/93139003.cms?from=mdr

61 WU Ping, Deputy Director China Manned Space Agency, China Manned Space Programme: Its Achievements and Future Developments, The 59th Session of COPUOS, Vienna, June 2016. https://www.unoosa.org/documents/pdf/copuos/2016/copuos2016tech20E.pdf

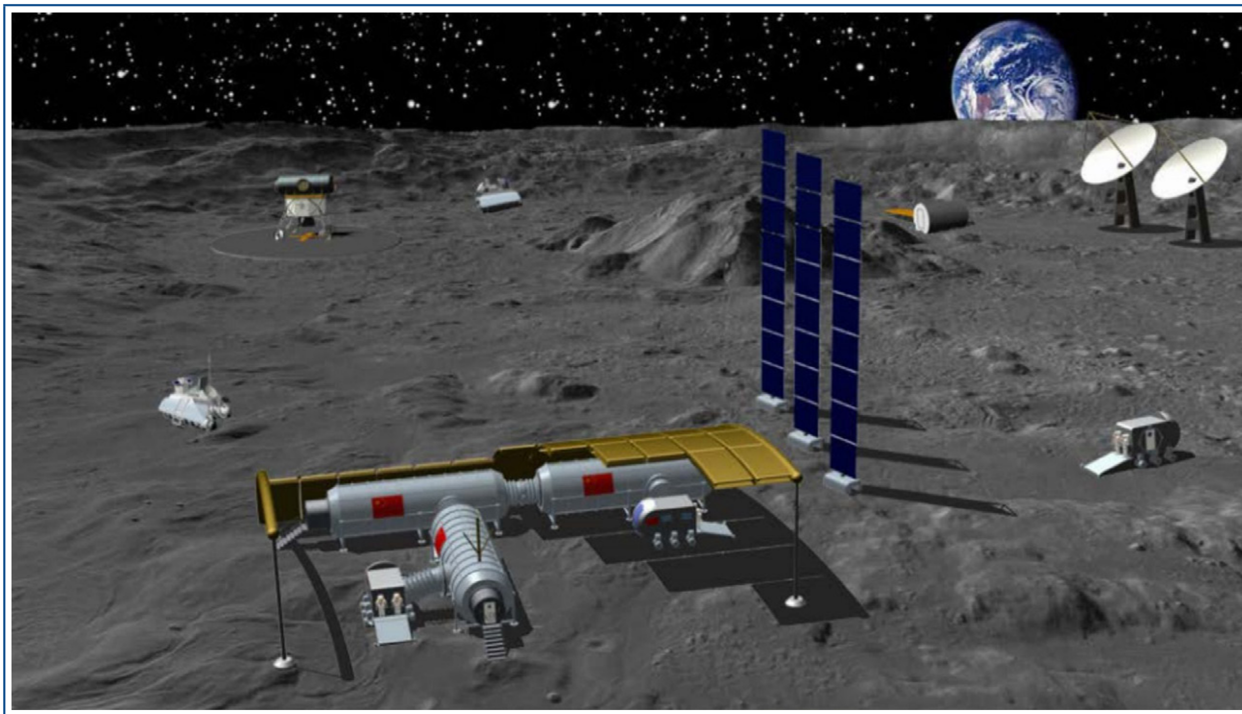
for sustained human stay in space, a precursor for activities on the moon.

ILRS Technological Aspects

Several types of technologies are needed for the establishment of a lunar base. For a moon station setup, the technologies that would broadly classify as the base requirements include a) multiple-use spacecraft, b) space infrastructure that would include remote sensing and moon observation satellites c) satellite communication and navigation systems d) human spaceflights e) space station technologies, f) deep space exploration capabilities and g) launch sites for extra-moon missions to mars, asteroids and space[62].

The ILRS will constitute a full-fledged translunar facility and will include a transportation facility, a long-term support facility, lunar transportation and operation facility, a scientific facility, application lab facility and a ground support facility[63,64]. A conceptual facility layout is shown in figure 22.

Figure 22: A conceptual impression of China's Lunar base *(Source: China Academy of Space Technology)*



62 Ibid, 2022.

63 CNSA, International Lunar Research Station (ILRS) Guide for Partnership, 2021. http://www.cnsa.gov.cn/english/n6465652/n6465653/c6812150/content.html

64 CNSA, International Lunar Research Station (ILRS) Guide for Partnership, 2021. http://www.cnsa.gov.cn/english/n6465652/n6465653/c6812150/content.html

The ILRS program is planned in three stages. The first phase is Reconnaissance (2021 to 2025), the second phase is Construction (2025-2030) and the third phase is Utilization which is 2035 and beyond[65].

To host a lunar base, the lunar environment needs to be addressed. It is dynamic and changes occur from place to place and under different temporality[66]. The temperature can vary from 374 K in the lunar day to 179 K in the lunar night[67].

The primary region of interest for a lunar base would be the lunar South pole with the promise of water-ice resource. For creating a habitat in this environment, the life support system would be of paramount importance which will support the habitation module. This would include a laboratory module as well. Other requirements for sustenance would include per capita consumption of thermal systems, insulation, radiation protection, oxygen, food, and water which will be required to go through the usual input-output cycle.[68]. Added to this is the choice of the Chinese ILRS in the southern polar regions or the dark zone or the far side of the moon. The significance of this region is the perpetual darkness-induced icy formations of the surface and any volatile produce of this region which might be in the frozen form. The polar regions of the south have a far greater number of permanently shadowed regions than the north pole region of the moon. Added to this is the fact that the lunar south pole is based in the largest and oldest lunar basin. This will be exploited for various studies for the habitat suitability of the region along with other resource benefits.

Russia is the main collaborator in ILRS and CNSA cooperation model with Russia lists the following:

A: General cooperation in the architecture of the ILRS and partnership for the construction of the ILRS.

B: Partner nations will include system and subsystem cooperation either with the Russian or Chinese space missions. Under this category, either of the partners will need to build independent components like robots, energy modules, etc.

C: The partners will be expected to cooperate for missions related to Chang'e or Luna series, which are subsequent missions for moon station establishments. Further, the partners will required to develop any subsystem like payload, communication, or navigation-related technologies. In the next category, the partners will be required to produce and supply one of the subsystems.

D: Finally, the partners are expected to

65 Op. cit. 15

66 Lisa C. Simonsen M4SA Langley Research Center Hampton VA 23665-5225 MarcJ.DeBarro Rockwell Interwational 12214 Lakewood Blvd. Downey CA 9()241 Jeffery T. Fanner M4SA Langley Research Center Hampton VA 23665-5225, CONCEPTUAL DESIGN OF A LUNAR BASE THERMAL CONTROL SYSTEM, N93-I4003, Lunar Base conference, 1992.

67 Ibid.

68 Michael Blanc, Planetory Exploration Horizon 2061 , A Long Term Perspective for Planetory Exploration, Elseiver, 2023.

contribute by developing application-related actions, constructing joint data centres and data analysis[69].

Comparison: ILRS Vs other Lunar Base Programmes

Besides ILRS, the other Lunar base and exploration plans are those of ESA and USA. In 2015 Director General of the European Space Agency introduced the concept of Moon Village[70]. It is said to be an extension of the concept of the International Space Station. ESA had identified a location in the south pole that has a convergence of near-perpetual light and ice in the permanently shaded region, thus maximizing the in-situ resource utilization[71]. One of the key interests among ESA members for exploration of the lunar base involves 'using the lunar surface for sustaining human surface exploration activities'[72]. The Moon Village has not made much progress and remains a conceptual plan.

The US plan centres around Artemis Missions. Artemis I was successfully completed in November/December 2022 and was an uncrewed test flight of the Orion Spacecraft. The subsequent flights involve a) crewed Artemis II flight but with no landing on the moon; b) Artemis III will land the first woman on the moon by 2024; and c) Artemis IV is scheduled for 2026 with the Habitat I-Hab.

Everyone's interest is in the resources on the moon which include large deposits of Helium 3, rare earth minerals and water[73]. The low gravity on the moon base is ideal for the launch of satellites and other space-borne instruments as well as flight for possible future of interplanetary travel. Thus, the moon could become the next real estate for contestation and conflict.

The Outer Space Treaty (1967) and the Moon Treaty (1979) try and consolidate the premise of inclusive sharing of resources and benefits from the moon for all mankind[74]. Artemis Accords as well as ILRS members may have different interpretations and approaches to lunar resources and lunar habitation. Hopefully, mutually agreeable rules of the road will emerge for sustainable habitation and resource utilization.

India-China Space Cooperation

India and China's space cooperation began in 2015 for bilateral cooperation in space. The initiative was to cater to the cooperation from 2015 to 2020. The agreement intended to reinforce cooperation in satellite remote

69 Ibid. 2021.

70 Agency, ESA Euronews: Moon Village, 2015, https://www.esa.int/Education/Teach_with_the_Moon/ESA_Euronews_Moon_Village

71 Leonard Davis, Mining the Moon, the Gateway to Mars, 2004. https://www.space.com/525-mining-moon-gateway-mars.html

72 Ibid, 2004.

73 Helium-3 mining on the lunar surface, European Space Agency.

74 Ram Jakhu, LL.M., D.C.L.; Associate Professor, Institute of Air and Space Law, Faculty of Law; McGill University, Montreal, Canada. This study was prepared as part of the Advanced Methods of Cooperative Security Program at the Center for International and Security Studies at the University of Maryland (U.S.), with generous support from the John D. and Catherine T. MacArthur Foundation. The author expresses his gratitude to several experts in the field of space law and policy (especially Jonathan Dean, Joanne I. Gabrynowicz, Nancy Gallagher, Francis Lyall and Ivan 1. Vlasic) who have reviewed an earlier version of the study and provided useful comments, LEGAL ISSUES RELATING TO THE GLOBAL PUBLIC INTEREST IN OUTER SPACE, Journal of Space law, Vol 32, 2006.

sensing, space-based meteorology studies, space science, lunar and deep space exploration, satellite navigation, space components, piggyback launch services and education and training. Apart from this, the Indian Institute of Astrophysics in Bangalore was among the selected team for an UN-led initiative to design a payload for the Chinese space station Tiangong. The Indian contribution was supposed to be in the Spectrographic Investigation of Nebular gases (SING) and was designed and developed by IIA, Bengaluru[75].

The cooperation has not really progressed much and space cooperation is not a priority for both countries. As of now, India-China cooperation in certain areas of ILRS seems rather remote but cannot be totally ruled out.

Conclusion

1. The ILRS will get established as planned. Besides Russia, some members of Asia-Pacific Space Cooperation Organisation (APSCO) may join ILRS in course of time.

2. The moon treaty is not popular and has been signed by few countries. Consequently, approach to sustainable lunar exploration, resource mining and processing, transportation, communication, emergency and safety issues need to be evolved under the auspices of UNOOSA.

3. Technology and resources permitting, India would like to perhaps have its own lunar base. India has already some elements and would be capable of developing other technologies for sustained visitation, habitation, exploration and resource utilization. While it hones its technological capabilities, India can achieve its goals faster in partnership with Artemis Accords countries rather than with ILRS.

75 Jacob Koshy, India-China dispute casts gloom over space project, The Hindu, New Delhi 2022, https://www.thehindu.com/news/national/india-china-dispute-casts-gloom-over-space-project/article65802105.ece

New instruments on lunar exploration and use: Implications for India

Upasana Dasgupta*

1. Introduction

In the second half of the last decade, the world witnessed humankind's renewed interest in planning missions to asteroids, the Moon and Mars. The renewed interest of humankind to venture to the Moon includes exploration, habitation and visitation in and around the Moon and regard it as the first step for traveling to other celestial bodies such as Mars. Many spacefaring countries have carried out lunar missions and more missions are planned in the years to come. Some of these will be crewed missions under the US Artemis Program and the China-Russia led International Lunar Research Station [ILRS]. As any other human activity, building human community in and around the Moon calls for laws governing it.

As part of the Artemis program, the USA has come up with the Artemis Accords which are "practical set of principles, guidelines, and best practices to enhance the governance of the civil exploration and use of outer space with the intention of advancing the Artemis Program". Similarly, the Chinese and Russian ILRS initiative of long-term exploration and utilization of the Moon invites all interested partners to cooperate and lays down the broad principles of cooperation - equality, openness and integrity.

Whereas attempts by States to formulate laws for governance of any activity is appreciable in the absence of any prior international law, such is not the case with lunar exploration. Humans have been to the Moon before and there are international instruments in place for governing such activities. In any case, reference to "outer space" usually means outer space including the Moon and other celestial bodies as is evident from the name and text of the OST,[76] which has been widely accepted and is ratified by 112 States. In addition, the OST makes explicit references to certain specific legal provisions which are applicable only to Moon and other celestial bodies and not to outer space void. For example, Article IV, Para 2 of the OST provides that the Moon and other celestial bodies should be used exclusively for peaceful purposes. Additionally, the Moon Agreement[77] is a subsequent treaty to the OST and specifically deals with governance of human space activities on the Moon and other celestial bodies. It may however, be noted that

* Assistant Professor, Jindal Global Law School, O.P. Jindal Global University.

76 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, January 27, 1967, online: https://www.unoosa.org/pdf/gares/ARES_21_2222E.pdf [OST]

77 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, 18 December 1979, online: https://www.unoosa.org/pdf/gares/ARES_34_68E.pdf [Moon Agreement].

this specific law on governance of space activities on the Moon and other celestial bodies has not gained popularity and has only been ratified by 18 States.[78] In any case, the OST governs both the outer space void and the Moon and the other celestial bodies and therefore, there exists an international governance mechanism for human space activities in the Moon and other celestial bodies.

In this chapter, I will first explore what are the existing international governance mechanisms for deep space exploration, particularly the OST and the Moon Agreement. Thereafter, I will discuss whether the new emerging instruments of lunar governance, namely the Artemis Accords and governing principles of ILRS, are consistent with the existing space law. This chapter also provides a detailed overview of the Artemis Accords and the ILRS initiative. Finally, the chapter discusses what should be India's stance regarding the joining the Artemis Accords and/or the ILRS initiative.

2. Artemis Accords and ILRS – Are they consistent with existing international space law?

The Artemis Accords reinforces certain provisions of the existing space law, most prominently the OST. However, it has certain provisions which may be viewed as violating the principle of non-appropriation of outer space. It can also be said to be having compatibility issues with the common heritage of mankind concept which is included in the Moon Agreement. The ILRS initiative has not released its governing principles but considering the race for hegemony between USA on one hand and Russia and China on the other, it is likely that the ILRS initiative will also justify certain acts of appropriation of outer space.

2.1 Existing space law on non-appropriation of outer space

The OST which applies to Moon and other celestial bodies, states that "[t]he exploration and use of outer space, including the moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind."[79] The OST also provides that "[o]uter space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means."[80]

The non-appropriation principle, apart from being included in the OST, can be said to be customary law that is applicable to all States, with the exception that it will not apply to any State if it has been a persistent objector of the custom during its formation. International customary law is a binding source of international law.[81]

78 Saudi Arabia gave notice of its withdrawal from the Moon Agreement on January 5, 2023 and the withdrawal will take effect on January 5, 2024 which will reduce the number of ratifications of Moon Agreement to 17 States from January 5, 2024. See, Saudi Arabia: Withdrawal, C.N.4.2023.TREATIES-XXIV.2 (Depositary Notification), online: <https://treaties.un.org/doc/Publication/CN/2023/CN.4.2023-Eng.pdf>.

79 OST, Article I

80 OST, Article II

81 Statute of the International Court of Justice, June 26, 1945, online: https://www.icj-cij.org/statute, Article 38(1)(b); Malcolm N Shaw, *International Law* (Cambridge University Press, 2008) at 70-71 (Although Article 38(1) of the ICJ Statute technically deals with sources of international law which the ICJ must apply, the formulation in Article 38(1) has been widely recognized as the "most authoritative and complete statement as to the sources of international law.")

In order to prove that a customary law exists, presence of two elements must be demonstrated - (a) State practice and (b) opinio juris.[82] The International Court of Justice in North Sea Continental Shelf Cases[83], observed:

> Not only must the acts concerned amount to a settled practice, but they must also be such, or be carried out in such a way, as to be evidence of a belief that this practice is rendered obligatory by the existence of a rule requiring it. The need for such a belief, i.e. the existence of a subjective element, is implicit in the very notion of the opinio juris sive necessitatis. The States concerned must therefore feel that they are conforming to what amounts to a legal obligation. The frequency, or even habitual character of the acts is not in itself enough. There are many international acts, e.g., in the field of ceremonial and protocol, which are performed almost invariably, but which are motivated only by considerations of courtesy, convenience or tradition, and not by any sense of legal duty.

While assessing evidence to ascertain whether there is general practice and on whether such practice is accepted as law, one has to look to "overall context, the nature of the rule and the particular circumstances in which the evidence in question is to be found."[84] It may be noted that verbal acts and not only physical acts of States count as fulfilling the State practice or objective element criteria. These verbal acts may be diplomatic statements, policy statements, statements in international organizations and resolutions that international bodies adopt.[85] Verbal acts also may embody the belief of States and thus satisfy the element of opinio juris.[86] Thus, resolutions of the United Nations General Assembly may in some instances constitute evidence of customary law though these resolutions are not binding per se.[87] Further,

82 Article 38(1)(b) of ICJ Statute provides that "international custom, as evidence of a general practice accepted as law" is a source of international law. See also, Continental Shelf (Libyan Arab Jarnahiriya/Malta), Judgment, I. C.J. Reports 1985, p. 13 at para 27; See also, "Identification of customary international law" UN GA Res 73/203 (2018), UN Doc A/ RES/73/203, Annex, Conclusion 2 [Through UN GA Res 73/203, the UN General Assembly welcomed the conclusion of International Law Commission's work on identification of customary international law. Conclusion 2 provides that an international custom has two constituent elements. It reads as follows "[t]o determine the existence and content of a rule of customary international law, it is necessary to ascertain whether there is a general practice that is accepted as law (opinio juris)."

83 *North Sea Continental Shelf (*Federal Republic of Germany/ Denmark; Federal Republic of Germany/ Netherlands), *Judgment,* I.C.J. Reports 1969, p 3 at 44.

84 "Identification of customary international law" UN GA Res 73/203 (2018), UN Doc A/ RES/73/203, Annex, Conclusion 3.

85 International Law Association, Final report of the Committee on Formation of Customary (general) International Law, London Conference (2000), Section 4, p. 14; "Identification of customary international law" UN GA Res 73/203 (2018), UN Doc A/ RES/73/203, Annex, Conclusion 6.

86 "Identification of customary international law" UN GA Res 73/203 (2018), UN Doc A/ RES/73/203, Annex, Conclusion 10.

87 International Law Association, Final report of the Committee on Formation of Customary (general) International Law, London Conference (2000), Section 28, p. 55; "Identification of customary international law" UN GA Res 73/203 (2018), UN Doc A/ RES/73/203, Annex, Conclusion 12.

omissions can count as a form of State practice[88] and acquiescence can be presumed to express opinio juris.[89]

The principle of freedom of exploration and use of outer space and related non-appropriation principle[90] was established when Sputnik was launched into outer space by erstwhile U.S.S.R. in 1957. Sputnik, once launched, circled above the Earth and yet the launching State did not seek any permission from other States and other States also did not protest. Thus, the freedom of exploration and use of outer space was "established and recognized as law within a remarkably short period of time."[91] In 1961, the UN General Assembly passed a resolution which "commends to States for their guidance in the exploration and use of outer space the following principles….[o]uter space and celestial bodies are free for exploration and use by all States in conformity with international law and are not subject to national appropriation."[92] Thereafter in 1962, the Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space provided as follows:

> "2. Outer space and celestial bodies are free for exploration and use by all States on a basis of equality and in accordance with international law. 3. Outer space and celestial bodies are not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means."[93]

In any case, the States took a stance during the beginning of Space Age that outer space is not subject to appropriation. In 1959, erstwhile Soviet Union's President Khrushchev assured that the Soviet Union had no intention of claiming the Moon as its territory.[94] The American President Lyndon B Johnson, in his Letter of Transmittal dated 7 February 1967 submitted to the Senate, advising on USA's ratification of the OST, recalled that:

> [i]n November 1958, President Dwight D Eisenhower asked me to appear before the United Nations to present the U.S. resolution [on outer space] … On that occasion, speaking for the United States, I said: 'Today, outer space is free. It is unscarred by conflict. No nation holds a concession there. It must remain this way. We of the United States do not acknowledge that there

88 International Law Association, Final report of the Committee on Formation of Customary (general) International Law, London Conference (2000), Section 6, p. 15.

89 "Identification of customary international law" UN GA Res 73/203 (2018), UN Doc A/ RES/73/203, Annex, Conclusion 10.

90 The principles are related because if national appropriation was allowed, there would not have been freedom of exploration and use of outer space for all.

91 *North Sea Continental Shelf* (Federal Republic of Germany/ Denmark; Federal Republic of Germany/ Netherlands), *Judgment,* I.C.J. Reports 1969, p 3, Dissenting opinion of Judge Manfred Lachs.

92 "International co-operation in the peaceful uses of outer space, UN GA Res 1721 A (XVI) (1961).

93 "Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space" UN GA Res 1962 (XVIII) (1963)

94 Cited in S.G. Sreejith, "Whither International Law, Thither Space Law: A Discipline in Transition", (2008) 38:2 California Western International Law Journal, Article 4.

> are landlords of outer space who can presume to bargain with the nations of the Earth on the price of access to this domain …' I believe those words remain valid today."[95]

In his famous 1962 speech, the then American President John F Kennedy stated, "We mean to lead [the exploration of space]. For the eyes of the world now look into space, to the moon and to the planets beyond, and we have vowed that we shall not see it governed by a hostile flag of conquest, but by a banner of freedom and peace."[96] The American delegate to UNCOPUOS, Mr. Herbert Reis, stated on 31 July 1969, just after the Apollo 11 astronauts had landed on the Moon, as follows "The negotiating history of the Treaty shows that the purpose of this provision (i.e. article II) was to prohibit a repetition of the race for the acquisition of national sovereignty over overseas territories that developed in the sixteenth, seventeenth, eighteenth and nineteenth centuries. The Treaty makes clear that no user of space may lay claim to, or seek to establish, national sovereignty over outer space ."[97] Later in the year, the NASA Authorization Act 1970 stated that planting of the American flag on the surface of the moon or any other planet "is intended as a symbolic gesture of national pride in achievement and is not to be construed as a declaration of national appropriation by claim of sovereignty."[98] Thus, freedom of exploration and non-appropriation of outer space are customary laws which will apply even to non-parties to the OST.

Later, the Moon Agreement was adopted. The Preamble of the Moon Agreement recognizes that the moon has an important role to play in exploration of outer space and benefits may be derived from the exploitation of the natural resources of the moon and other celestial bodies. The Moon Agreement provides that the provisions relating to the moon shall also apply to other celestial bodies within the solar system unless specific legal norms are entered with respect to any of these celestial bodies.[99]

It has been construed by many that the Moon Agreement does not allow use of space resources. Moon Agreement actually, provides that in carrying out scientific investigations, State Parties have the right to collect and remove from moon samples of its mineral and other substances.[100] It may be stated here that Article 1(1) of OST provides exploration and use of outer space shall be carried out for the benefit of all countries and is declared to be the "province of all mankind" and puts conditions on freedom of States to explore and use outer space only for their own benefit. The concept of common heritage of mankind goes further

95 Cited in Steven Freeland and Ram Jakhu, "Article II" in Stephan Hobe et all, *Cologne commentary on space law. Vol. 1, Outer space treaty* (Carl Heymanns Verlag, Cologne, 2009) at 51.

96 USA President John F Kennedy, "Address at Rice University on the Nation's Space Effort", 12 September, Houston, Texas, USA, online: < https://www.jfklibrary.org/learn/about-jfk/historic-speeches/address-at-rice-university-on-the-nations-space-effort>.

97 Cited in Steven Freeland and Ram Jakhu, "Article II" in Stephan Hobe et all, *Cologne commentary on space law. Vol. 1, Outer space treaty* (Carl Heymanns Verlag, Cologne, 2009) at 49.

98 National Aeronautics and Space Administration Authorization Act 1970, online: < https://www.congress.gov/bill/91st-congress/house-bill/11271/text>.

99 Moon Agreement, Article 1(1).

100 Moon Agreement, Article 6(2).

than the province of all mankind and leaves it open for an international regime to be created for explotitation of resources of the Moon and other celestial bodies, once exploitation of natural resources become feasible.[101] It is felt that the idea of Common Heritage of Mankind [CHM] enshrined in Article 11 of the Moon Agreement is perceived by the big space powers as not conducive to their interests[102]. First proposed by Argentina's Ambassador A.A. Cocca, the principle of Common Heritage of Mankind has been incorporated in the Moon Agreement[103] but due to general lack of understanding of the concept, has been highly contested. This factor as well as misperceptions regarding CHM are the reasons for low count ratification of the Moon Agreement.

The Moon Agreement also provides that the international regime under CHM shall include the following[104]:

(a) The orderly and safe development of the natural resources of the moon;

(b) The rational management of those resources which will ensure that resource wasting is avoided.

(c) The expansion of opportunities in the use of those resources

(d) An equitable sharing by all States Parties in the benefits derived from those resources, whereby the interests and needs of the developing countries, as well as the efforts of those countries which have contributed either directly or indirectly to the exploration of the moon, shall be given special consideration. It may be noted here that the Moon Agreement provides for "equitable" sharing of benefits. This means States that directly or indirectly contribute to the management of resources will enjoy a special position. Developing countries are also to benefit, irrespective of their investment.

The CHM concept in Moon Agreement simply provides for setting up a regime by the Member States of the Moon Agreement for sharing of benefits on an equitable basis. Yet, many, especially the technologically advanced space powers perceive this as a restriction on the commercial utiilization of space resources. For example, the US Army Space Reference Text on Space Policy and Law mentions that "the moon is a common heritage for all mankind which implies that all nations would share equally in any benefits derived from moon exploration. If the U.S. signed this treaty it would be hard to get private firms to invest in future moon projects if they had to divide the profits."[105] This is incorrect statement as the CHM requires equitable sharing of resources taking into interests of all States and does not require equal sharing. Also, confusion regarding the interpretation of CHM might arise while drawing a parallel from the law of the sea. This view might be influenced by the

101 Moon Agreement 11(1) and 11(5)

102 Tronchetti, F. (2010). The moon agreement in the 21st century: addressing its potential role in the era of commercial exploitation of the natural resources of the moon and other celestial bodies. Journal of Space Law, 36(2), 489-524.

103 Ram Jakhu, "Twenty Years of the Moon Agreement: Space Law Challenges for Returning to the Moon" (2005) 54 Zeitschrift Für Luft-und Weltraumrecht, 243

104 Moon Agreement, Article 11(7)

105 Cited in Ram Jakhu, "Twenty Years of the Moon Agreement: Space Law Challenges for Returning to the Moon" (2005) 54 Zeitschrift Für Luft-und Weltraumrecht, 243.

fact that even before the existing CHM concept in law of sea was adopted in 1994, imposing fewer mandatory obligations on developed States, there were multiple proposals including one that CHM will allow mandatory transfer of technology in high seas. It must be reiterated that irrespective of CHM negotiations in other fields of law, Moon Agreement does not impose moratorium on space benefit sharing and in fact encourages the Member States to multilaterally develop a benefit sharing regime.

2.1. Are Artemis Accords and ILRS consistent with the OST?

The Artemis Accords claims to be in compliance with the OST. It may be noted that the OST was drafted based on the geopolitics and technologies of the 1960s and 1970s and as such, suffers from some inadequacies. For example, the OST does not clearly provide whether the non-appropriation principle includes prohibition on space resources extraction and there is no existing law on safety zones. In this regard, some commentators have opined that space resource extraction is prohibited under the OST, others have stated that space resource extraction does not, per se, amount to appropriation. In fact, space resource extraction can be said to be an "use" of outer space and hence be governed by the freedom of exploration and "use" of outer space.

Those who believe that the OST prohibits space resource extraction, note that the OST provides for non-appropriation by sovereignty, use or occupation or " by any other means". Thus, non-appropriation does not simply mean prohibition on appropriation by sovereignty only and includes appropriation by any other means too. The phrase "by any other means" is a catch-all phrase intended to ensure that no form of appropriation of outer space takes place.

However, the OST does not explicitly mention space resources and their extraction and hence, as the relevance of space resource extraction was understood, certain States took the stance that space resource extraction should be encouraged and brought changes in the national laws explicitly allowing space resource extraction. These new laws gave the entities, interested in space resource extraction, a degree of certainty and a climate of encouragement.

In 2015 USA passed the Space Resource Exploration and Utilization Act of 2015. The Act states that it will "facilitate the commercial exploration for and commercial recovery of space resources by United States citizens" and "discourage government barriers to… commercial exploration for and commercial recovery of space resources in manners consistent with the international obligations of the United States…"[106] The said Act further stated that "A United States citizen engaged in commercial recovery of an asteroid resource or a space resource under this chapter shall be entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell the asteroid resource or space resource obtained in accordance with applicable law, including the international obligations of the United States."[107] It may be noted that simply including the phrase "consistent with the existing international obligations of the United States" does not resolve actual inconsistency between the domestic law and USA's international obligations. Such an interpretation by the USA through its national

106 Space Resource Exploration and Utilization Act of 2015, § 51302

107 Space Resource Exploration and Utilization Act of 2015, § 51303

law that non-appropriation principle allows extraction of sources was criticized by some as a unilateral act[108], and by some as straight up violation of OST.[109] Furthering on the lines of 2015, in 2020, the then USA President Trump passed on Executive Order.[110] The Executive Order was passed in order to remove the "uncertainty regarding the right to recover and use space resources, including the extension of the right to commercial recovery and use of lunar resources" which has discouraged some commercial entities. It goes on to further state that "Americans should have the right to engage in commercial exploration, recovery, and use of resources in outer space, consistent with applicable law. Outer space is a legally and physically unique domain of human activity, and the United States does not view it as a global commons."[111] The Artemis Accords keeps in mind the indeterminacy of law of appropriation in OST and builds on US domestic laws to arrive at an interpretation of non-appropriation principle allowing space resource extraction.

Non-appropriation principle permitting space resource extraction was also taken by Luxembourg. Luxembourg's 2017 law on the exploration and use of space resources provides that space resources are capable of being appropriated.[112] Thus, Luxembourg believes that there is difference between appropriation of celestial bodies themselves and appropriation of resources in such celestial bodies. United Arab Emirates too passed a law in 2019[113] which, inter alia, allowed extraction of space resources. The law allows "exploration, exploitation and use of Space Resources, including their acquisition, purchase, sale, trade, transportation, storage."[114] It may be noted that Luxembourg and United Arab Emirates are two of the eight founding signatories of the Artemis Accords. Artemis Accords state that "[t]he Signatories affirm that the extraction of space resources does not inherently constitute national appropriation under Article II of the Outer Space Treaty…"[115] Similarly, the Artemis Accords allow safety zones in Moon to be demarcated to avoid deconfliction

108 Report of the Legal Subcommittee on its fifty-fifth session, held in Vienna from 4 to 15 April 2016, A/AC.105/1113, online: < https://documents-dds-ny.un.org/doc/UNDOC/GEN/V16/024/84/PDF/V1602484.pdf?OpenElement>, paras 75, 79.

109 *Ibid,* para 74.

110 USA, Executive Order on Encouraging International Support for the Recovery and Use of Space Resources, April 6, 2020, online: < https://trumpwhitehouse.archives.gov/presidential-actions/executive-order-encouraging-international-support-recovery-use-space-resources/>.

111 *Ibid,* Sec 1.

112 Loi du 20 juillet 2017 sur l'exploration et l'utilisation des ressources de l'espace, Article 1, online: https://legilux.public.lu/eli/etat/leg/loi/2017/07/20/a674/jo> (Article 1 states "Les ressources de l'espace sont susceptibles d'appropriation.")

113 United Arab Emirates' Law of 2019 on the Regulation of the Space Sector, online: < https://www.moj.gov.ae/assets/2020/Federal%20Law%20No%2012%20of%202019%20on%20THE%20REGULATION%20OF%20THE%20SPACE%20SECTOR.pdf.aspx>.

114 United Arab Emirates' Law of 2019 on the Regulation of the Space Sector, online: < https://www.moj.gov.ae/assets/2020/Federal%20Law%20No%2012%20of%202019%20on%20THE%20REGULATION%20OF%20THE%20SPACE%20SECTOR.pdf.aspx>, Article 18(1).

115 Artemis Accords, Section 10

and avoid harmful interference. Such safety zones may be viewed by some as exclusion zones and thus violative of non-appropriation of outer space principle.

While being critical of the Artemis Accords, the Russian and Chinese thoughts appear to interpret that non-appropriation principle allows space resource extraction. In a 2014 draft program issued by Roscosmos, Russian scientists and academics outlined a three-step plan toward human settlement of moon and setting up infrastructure for a colony using local resources.[116] Thus, despite being critical of the Artemis Accords, Russia itself may also adopt the interpretation that non-appropriation principle allows extraction of space resources and safety zones.

The Chinese media on the other hand, labelled Artemis Accords as "disingenuous attempt to stymie Chinese space ambitions". The Chinese viewed the Artemis Accords as "unembellished and preposterous attempt" to unilaterally set ground rules for lunar resource exploitation.[117] However, Ma Zhanyuan, a Professor at the Chinese University of Law and Political Science, noted that there was a legal vacuum regarding lunar resource extraction but any framework to regulate such extraction should be for the benefit of all States.[118] Thus, despite criticism of Artemis Accords, Chinese scholars seem to lean towards the interpretation that non-appropriation principle allows space resource extraction. Further, there have been reports as early as 2003 which note that China is interested in resources of the moon.[119]

The ILRS was unveiled in 2021, a few months after the text of Artemis Accords, was made public.[120] Though the governing principles of the ILRS are not yet decided, the Joint statement between CNSA and ROSCOSMOS in April 2021 promised to open the project to all potential international partners for cooperation.[121] From the documents available publicly such as the ILRS Guide for Partnership, ILRS initiative will welcome all international partners indiscriminately and the framework will be based on equality, openness and integrity. In any case, it will be possible to comment on China and Russia's ILRS initiative once the guiding principles are made public. Further, despite the criticism of Artemis Accords by Russia and China, it is believed that they plan to compete with the USA for hegemony in deep space exploration.

2.2. Are Artemis Accords principles consistent with the Moon Agreement?

Unilateral interpretation of non-appropriation principle to allow space resource extraction may be discouraged, but it cannot be denied that as

116 "Russia Plans Long-Term Base on the Moon — Space Agency" *The Moscow Times,* November 6, 2018, online: < https://www.themoscowtimes.com/2018/11/06/russia-plans-long-term-base-on-moon-space-agency-a63406>.

117 *Ibid.*

118 *Ibid.*

119 "Space could be Chinese by the year 2050, experts say" (Beijing, Oct 16, 2003), http://www.spacedaily.com/2003/031016024357.yvvtcqwo.html .

120 The text of Artemis Accords was made public on October 13, 2020.

121 See also, "China and Russia Welcome International Participation in Lunar Research Station Project" , *Bulletin of the Chinese Academy of Sciences,* June 20, 2021, online: < http://www.bcas.cas.cn/infocus/202106/t20210620_272289.html>.

natural resources are depleting on Earth, we have to at some point begin relying on celestial bodies for such resources. In fact, the Moon Agreement, which is a treaty that came subsequent to OST, explicitly provides that exploitation of moon resources can be carried out, provided the State parties to the Moon Agreement agree to a benefit-sharing regime that is equitable. It may be noted though that unfortunately after adoption by UN General Assembly, once the Moon Agreement opened for signature, it did not get enough support. The Moon Agreement has only 18 State parties since its entry into force and none of the major spacefaring States have ratified it.[122]

Though Artemis Accords does not mention Moon Agreement anywhere in its text and USA has vehemently opposed the Moon Agreement in the recent past[123], it does not necessarily mean that the Artemis Accords are inconsistent with Moon Agreement. In fact, countries such as Australia, France and Mexico are party to both Moon Agreement and the Artemis Accords and have taken the position that the Artemis Accords are consistent with their international legal obligations.[124]

A few points of divergence between the Moon Agreement and Artemis Accords are listed below:

(a) Whereas Moon Agreement provides for coordination with other States if operating in same orbit or areas[125] and avoid harmful interference with space activities of other States;[126] Artemis Accords addresses the harmful interference issue through creation of reasonable, temporary "safety zones."[127] Safety zones do not find mention in the Moon Agreement and in principle infringe on the non-appropriation aspect. In any case, safety zones are not recognized as State practice in international law.

(b) Moon Agreement explicitly allows use of space resources to support scientific missions only;[128] whereas Artemis Accords allows extraction of space resources that

122 It will be 17 once Saudi Arabia's withdrawal process from the Moon Agreement is completed in January 2024. , on 5 January 2023, Saudi Arabia notified the UN Secretary General its decision to withdraw from the Moon Agreement with effect from 5 January 2024 in accordance with Article 20 of the Moon Agreement. Though Saudi Arabia has not provided any reason for such withdrawal nor is it required to provide any reason under law.

123 In 2020 Executive Order, USA reiterated its position on the Moon Agreement. The Executive Order provides as follows:

Sec. 2. The Moon Agreement. The United States is not a party to the Moon Agreement. Further, the United States does not consider the Moon Agreement to be an effective or necessary instrument to guide nation states regarding the promotion of commercial participation in the long-term exploration, scientific discovery, and use of the Moon, Mars, or other celestial bodies. Accordingly, the Secretary of State shall object to any attempt by any other state or international organization to treat the Moon Agreement as reflecting or otherwise expressing customary international law. USA, Executive Order on Encouraging International Support for the Recovery and Use of Space Resources, April 6, 2020, online: < https://trumpwhitehouse.archives.gov/presidential-actions/executive-order-encouraging-international-support-recovery-use-space-resources/>.

124 "The New SpaceEra: What Do the Artemis Accords Mean for International Space Law" (Donna Lawler), online:< https://www.facebook.com/watch/live/?ref=watch_permalink&v=236078594718341>

125 Moon Agreement, Article 5

126 Moon Agreement, Article 8

127 Artemis Accords, Section 11

128 Moon Agreement, Article 6

can benefit humankind through safe and sustainable operations.

(c) Moon Agreement provides that Moon is CHM and an equitable regime for benefit sharing should be developed multilaterally by State parties[129]; the Artemis Accords provide that "[t]he Signatories intend to use their experience under the Accords to contribute to multilateral efforts to further develop international practices and rules applicable to the extraction and utilization of space resources, including through ongoing efforts at the COPUOS."[130] This could mean extraction of space resources could precede the evolution of best practices and rules. Similar view had also been expressed by some delegations in LSC-COPUOS 2016 who said that national positions on resource extraction does not preclude a multilateral mechanism to be developed in the future.[131]

(d) Both OST[132] and Moon Agreement[133] provide that the Moon shall be used by all States exclusively for peaceful purposes. Artemis Accords deal with peaceful civil activities by civil space agencies[134] which leaves open the question whether there could be other activities on the Moon which may not be classified peaceful.

(e) Moon Agreement considers protecting international scientific preserves[135] while Artemis Accords deals with preservation of outer space heritage.[136]

2.3. Artemis Accords and ILRS bypass multilateralism

Artemis Accords is criticized for its attempt of bypassing multilateralism, which could be pursued under the aegis of the United Nations. As NASA's website makes it clear that while international cooperation is sought, the Artemis mission is an American initiative, is led by the USA and the mission aims to expand USA's global economic impact.[137] The Artemis Accords thus promotes USA's interpretation of the existing

129 Moon Agreement, Article 11

130 Artemis Accords, Section 10(4)

131 Report of the Legal Subcommittee on its fifty-fifth session, held in Vienna from 4 to 15 April 2016, A/AC.105/1113, online: < https://documents-dds-ny.un.org/doc/UNDOC/GEN/V16/024/84/PDF/V1602484.pdf?OpenElement>, para 80

132 Outer Space Treaty, Article IV

133 Moon Agreement, Article 3

134 Artemis Accords, Section 1

135 Moon Agreement, Article 7(3)

136 Artemis Accords, Section 9

137 NASA website states as follows: "While NASA is leading the Artemis missions, international partnerships will play a key role in achieving a sustainable and robust presence on the Moon while preparing to conduct a historic human mission to Mars". Artemis Accords, online: <https://www.nasa.gov/specials/artemis-accords/index.html>. The website also states that with Artemis, the USA will "[e]stablish American leadership and a strategic presence on the Moon while expanding our U.S. global economic impact", NASA, "What is Artemis?", online: <https://www.nasa.gov/what-is-artemis>. In the Artemis plan, it is stated "With clear direction from the White House, coordination among the reestablished National Space Council, strong bipartisan support in Congress, and robust participation from industry and international partnerships, Artemis is a globally unifying endeavor. America will lead the monumental shift that frees humanity from our innate bonds to Earth." NASA, "The Artemis Plan", online: <https://www.nasa.gov/sites/default/files/atoms/files/artemis_plan-20200921.pdf>.

space law and such unilateral interpretation undermines the multilateral space treaties. It must be noted here that multilateralism, as it stands today, may not be panacea to all the problems in the world but multilateralism is "more than mere friendly relations among states; it is an antithesis to unilateralism, thus containing within it the requirement of commonly respected legality and widely supported legitimacy."[138]

As Artemis Accords already has 23 Signatories, it may seem to be it is after all a multilateral document, albeit not under the aegis of the United Nations. However, such a view cannot hold as the Artemis Accords bypasses the multilateral mechanism of law making where all interested States are involved and there is decision making either through consensus or majority decision. Though feedback from potential international partners was sought by the USA while drafting the Artemis Accords, the final text was adopted by the USA.[139] The Artemis Accords provides the guiding principles of long-term deep space exploration in a 'take it or leave it' format for the potential signatories as the text of the Artemis Accords has already been decided by the USA.

A true multilateral effort should be open for negotiation by all States and unilateral adoption of instruments on space resource extraction are inadequate to ensure that such resource extraction, if and when it occurs, takes place in a "safe and sustainable manner."[140] Though Artemis program aims to cooperate with USA's traditional and non-traditional partner countries[141], this American led program is bound by USA's own national laws which imposes restrictions on USA's space cooperation with certain countries. The USA's Wolf Amendment 2011 prohibits NASA from using governmental funds for direct, bilateral cooperation with China and Chinese affiliated entities, without explicit authorization from the Federal Bureau of Investigation and the US Congress.[142] This provision has been inserted annually in American yearly appropriation acts since 2011 and is included in the Consolidated Appropriations Act, 2023.[143] Thus, there are restrictions under USA's domestic laws to cooperate with certain countries and it may be difficult under it to allow these States to be part of the Artemis Accords. Hence, signing of Artemis Accords is not open to all States and thus is not truly multilateral.[144]

It may be noted multilateralism need not mean acting under the aegis of the United Nations. Actions that begin as unilateral acts may at a later point become a multilateral effort. Artemis

138 Mogami Toshiki, "Legality, Legitimacy, and Multilateralism" *Un Chronicle,* online: <https://www.un.org/en/chronicle/article/legality-legitimacy-and-multilateralism>, See generally, . Jose E. Alvarez, Multilateralism and Its Discontents, 11 EUR. J. INT'L L. 393, 394 (2000).

139 Mike Gold, IASL-IAASS Webinar Series I Artemis Accords: Challenges & Opportunities, (Recording), online: < https://www.mcgill.ca/iasl/iasl-webinar-series/space-law-webinar-series#Artemis%20Accords>

140 Outer Space Institute, Vancouver Recommendations on Space Mining, (April 20, 2020), online: <https://www.outerspaceinstitute.ca/docs/Vancouver_Recommendations_on_Space_Mining.pdf>.

141 Mike Gold, IASL-IAASS Webinar Series I Artemis Accords: Challenges & Opportunities, (Recording), online: < https://www.mcgill.ca/iasl/iasl-webinar-series/space-law-webinar-series#Artemis%20Accords>

142 USA, Department of Defense and Full-year Continuing Appropriation Act 2011, online: <https://www.congress.gov/112/plaws/publ10/PLAW-112publ10.htm>.

143 USA, Consolidated Appropriations Act, 2023, H.R. 2617, Title V, Sec 526, online: <https://www.govinfo.gov/app/details/BILLS-117hr2617enr>.

144 Similar anomalies exist in several international organizations where new members can be added only by consensus

Accords can also become a true multilateral effort if it incorporates within it the CHM concept. Incidentally, in 2022, the Legal Subcommittee of the COPUOS created a Working Group on the Legal Aspects of Space Resource Activity. The said working group's mandate includes assessing the benefits of further development of a framework for activities in the exploration, exploitation and utilization of space resources, including by way of additional international governance instruments; and developing a set of initial recommended principles for such activities which will be considered as consensus agreement by the UNCOPUOS, followed by possible adoption by the General Assembly as a dedicated resolution or other instruments.[145] The said working group has a mandate of five years i.e. from 2023 to 2027.[146]

It may be noted that Section 2 of the Artemis Accords provides that the implementation of the cooperative activities may be implemented through appropriate instruments, such as Memoranda of Understanding, Implementing Arrangements under existing Government-to-Government Agreements, Agency-to-Agency arrangements, or other instruments. While text of the Artemis Accords has been already decided and signatories may either take it or leave it, the same formula should not applied in its implementing agreements. Through these implementing agreements, the confusion created by Artemis Accords may be cleared and concepts in Moon Agreement can be included. Further, as NASA enters into bilateral agreements with space entities wishing to join the Artemis Accords, there is scope for incorporating mutually acceptable terms including issues related to safe and sustainable use of resource extraction and utilization.

It must be mentioned that there is not much publicly available information on guiding principles of Sino-Russian ILRS program. While the available documents provide that the program will be open to all interested international partners, and will be based on equality, openness, and integrity, it is difficult to comment on the program until the governing principles are made available publicly or discussed publicly.

2.4. Legal Status of the Artemis Accords

As Section 1 of the Artemis Accords states, it represents a political commitment. Besides, Section 13(2) of the Artemis Accords clearly provides that the Artemis Accords is "not eligible for registration under Article 102 of the Charter of the United Nations".[147] Article 102(1) of the UN Charter provides that every treaty and every international agreement that member States of the UN enter into, after coming into force of the UN Charter, shall be registered with the UN Secretariat.[148] Hence, as the Artemis Accords are not eligible to be registered under Article 102 of the UN Charter, it is not a treaty. It may be noted here that treaties represent binding obligations between the State parties under international law, which must be performed by the State parties

145 Report of the Committee on the Peaceful Uses Outer Space at its sixty-fourth session in 2021 (A/76/20 , Annex III), online: <https://www.unoosa.org/oosa/oosadoc/data/documents/2021/a/a7620_0.html>

146 Report of the Legal Subcommittee at it sixty-first session in 2022, A/AC.105/1260, Annex II, Appendix, online: https://www.unoosa.org/oosa/oosadoc/data/documents/2022/aac.105/aac.1051260_0.html.

147 The Artemis Accords, Section 13(2).

148 Charter of the United Nations, Article 102(1)

in good faith.[149] Artemis Accords is not a treaty and its principles thus, do not create binding treaty commitments. Based on its non-binding nature and it being a non-treaty, some believe that Artemis Accords cannot be conflicting to existing treaties. However, Artemis Accords is a process of negotiating customary international law in outer space and joining Artemis Accords may be viewed as a process towards amending some provisions of the OST and the Moon Agreement.[150]

3. Emerging instruments with renewed interest in lunar exploration: An overview

2.3. Artemis Accords

The Artemis program is the USA's first step in sustained venturing out to celestial bodies beyond Earth and one of the aims of the program is to land the first women and the first person of color on the Moon by 2024. In line with this, NASA has named on April 03, 2023 the Artemis 2 astronaut crew for the first lunar mission since Apollo[151]. The Artemis Accords was launched on 13 October 2020, was signed by first eight partner countries initially and had 23 signatories as on March 31, 2023.[152] The Artemis Accords will be implemented through bilateral agreements which will, inter alia, lay down responsibilities of the involved partners.[153]The Artemis Accords provide that the purpose of the Accords "is to establish a common vision via a "practical set of principles, guidelines, and best practices to enhance the governance of the civil exploration and use of outer space with the intention of advancing the Artemis Program."[154] The Artemis Accords further provides that these practical set of principles, guidelines and best practices in carrying out space activities are intended to "increase the safety of operations, reduce uncertainty, and promote the sustainable and beneficial use of space for all humankind"[155]. So, prima facie, Artemis Accords is aimed to advance its Artemis program and to ensure that as more States and private players venture into deep space exploration, they do not affect each other's safety of operations and to bring certainty regarding the legal regime governing such deep space exploration. NASA's promotional presentation provides that "international cooperation on Artemis is intended not only to bolster space exploration but to enhance

149 Vienna Convention on the Law of Treaties, May 23, 1969, online: <https://legal.un.org/ilc/texts/instruments/english/conventions/1_1_1969.pdf>; See also, Statute of the International Court of Justice, June 26, 1945, online: https://www.icj-cij.org/statute

150 Shakeel Ahmad, "Space Exploration and Making of International Space Law: An Analysis on Artemis Accords", paper delivered at APSCO/AUASS International Symposium 2022, Space Exploration- Moon and beyond, Mafraq, Jordan, (November 2022).

151 Space.com. Four for the Moon! NASA names Artemis 2 astronaut crew for 1st lunar mission since Apollo. (2023, April 03). https://www.space.com/nasa-names-artemis-2-moon-crew

152 Artemis Accords, online: <https://www.nasa.gov/specials/artemis-accords/index.html>

153 NASA, NASA, International Partners Advance Cooperation with First Signings of Artemis Accords, Press Release, online: <https://www.nasa.gov/press-release/naa-international-partners-advance-cooperation-with-first-signings-of-artemis-accords>.

154 The Artemis Accords - Principles for Cooperation in the Civil Exploration and Use of the Moon, Mars, Comets, and Asteroids for peaceful purposes, online: https://www.nasa.gov/specials/artemis-accords/img/Artemis-Accords-signed-13Oct2020.pdf [Artemis Accords]

155 *Ibid.*

peaceful relationships between nations."[156] It may be noted that though States are signatories to the Artemis Accords, the civil space activities by the space agencies of the Signatory States carry out the cooperative efforts.[157]

The Artemis Accords includes the following principles:

(a) Peaceful purposes - Cooperative activities under the Artemis Accords shall be exclusively for peaceful purposes

(b) Transparency - Commitment of Signatories to transparency and dissemination of information

(c) Interoperability - Interoperability through development of interoperable and common exploration infrastructure and standards

(d) Emergency Assistance - Providing necessary assistance to personnel in outer space who are in distress as per Rescue and Return Agreement.[158]

(e) Registration of space objects - Cooperate to consult and determine which State should register any relevant space object in accordance with the Registration Convention.[159]

(f) Release of Scientific Data - Open sharing of scientific data and Signatories retain the right to communicate and release information regarding their activities to the public.

(g) Preserving Outer Space Heritage - Preservation of outer space heritage, especially historically significant human or robotic landing sites, artifacts, spacecraft, and other evidence of activity on celestial bodies.

(h) Space Resources - Extraction and utilization of space resources including from the surface or subsurface of the Moon, Mars, comets, or asteroids.

(i) Deconfliction of Space Activities and safety zones - Deconfliction of space activities through safety zones which are areas where operations of a relevant activity or an anomalous event could reasonably cause harmful interference with other space activity.

(j) Orbital Debris and spacecraft disposal- Commitment to mitigation of orbital debris, including the safe, timely, and efficient passivation and disposal of spacecraft at the end of missions.

The Artemis Accords provides that many of the principles included in it provide for "operational implementation of important obligations contained in the Outer Space Treaty and other

156 NASA, "The Artemis Accords - Principles for a Safe, Peaceful, and Prosperous Future", online: <https://www.nasa.gov/specials/artemis-accords/img/Artemis-Accords_v7_print.pdf>

157 The Artemis Accords, Section 1

158 Agreement on the rescue of astronauts, the return of astronauts and the return of objects launched into outer space, April 22, 1968, online: <https://www.unoosa.org/pdf/gares/ARES_22_2345E.pdf>.

159 Convention on Registration of Objects Launched into Outer Space, January 14, 1975, online: <https://www.unoosa.org/pdf/gares/ARES_29_3235E.pdf>.

instruments".[160] Though Artemis Accords affirms many principles of the OST and other space treaties, as discussed in the section above, concepts such as safety zones and space resource extraction need further discussion and a multilaterally acceptable approach.

3.2. International Lunar Research Station

China National Space Administration (CNSA) and Russia's State Space Corporation Roscosmos jointly initiated the International Lunar Research Station (ILRS) project which aims to set up a base near the moon's south pole. There are three phases of the project - reconnaissance, construction and utilization. ILRS will be ready to host crewed missions by 2030.[161]

On March 9, 2021, China and Russia signed the Memorandum of Understanding regarding cooperation for the construction of the International Lunar Research Station. On April 23, 2021, a "Joint statement of the China National Space Administration and the State Space Cooperation "Roscosmos" Regarding Cooperation for the construction of the International Lunar Research Stations" was issued. On June 16, 2021, "Roadmap of ILRS (V1.0)" and " ILRS Guide for Partnership" was released.

Unlike Artemis project's Artemis Accords, ILRS project has not proposed any instrument laying down its governing principles and lacks at the moment a clear arrangement and a cooperative framework. However, the ILRS Guide for Partnership acknowledges that the "most efficient and productive investigation, exploration and use of the Moon" can be achieved through broad international partnership between other countries, international organizations and international partners. The ILRS Guide for Partnership lays down that the peaceful exploration and use of the Moon shall be in the interests of all humankind and shall adhere to principles of equality, openness and integrity.[162] In the Cooperation Guidelines section of the ILRS Guide for Partnership document, details regarding (a) cooperation domains (b) cooperation classification and (c) cooperation organization, are provided.

Cooperation domain includes, inter alia, the following:

(a) "Strategy development and coordination related to the Moon exploration and use, defining of areas of cooperation and planning including development of the roadmap with regard to the exploration and use of the Moon"

(b) "Joint development of the legal documents regulating relations, including the involvement in cooperation of third parties, in the framework of creation of ILRS"

(c) "Review of existing standards in the field of launch vehicle and spacecraft technology development and potential definition of future standards that may be used during the creation of ILRS."

160 The Artemis Accords, Section 1.

161 Kerry Hebden, "China envisions crewed moon missions by 2030", ROOM , December 20, 2021, online: <https://room.eu.com/news/china-envisions-crewed-moon-missions-by-2030>.

162 International Lunar Research Station, ILRS, Guide for Partnership (V1.0), June 2021, online: <http://www.cnsa.gov.cn/english/n6465652/n6465653/c6812150/content.html>

Cooperation Classification classifies cooperation by international partners in 5 categories - (a) space mission cooperation (b) space system cooperation (c) subsystem cooperation (d) equipment cooperation (e) ground and application cooperation. All interested international partners are encouraged to join the project based on their own circumstances and situation. China and Russia welcome international partners for all phases of exploration and use of the moon and in all-hierarchy levels of each phase.[163]

The organization in charge of the cooperative efforts of ILRS is the inter-agency joint working group of ILRS. Currently, the joint working group comprises representatives of China and Russia under which there are subgroups for legal affairs, science and engineering.

Though ILRS initiative consists of only two partners at the moment, discussions are underway regarding Venezuela and Brazil to be partners for the project.[164] Interestingly, Brazil is already a signatory of the Artemis Accords.

It may be noted however, the "Declaration on the International Lunar Research Station" is being drafted jointly by Russia and China and it will clarify the general principles, ways of participation and guidelines for activities of the ILRS.[165]

4. Should India be part of the emerging instruments on lunar exploration?

4.1. India and Artemis Accords

India has been potentially considering signing of Artemis Accords since 2021.[166] In fact, India has been participating in the Artemis program as of October 2022 and has signed certain instruments including an implementing arrangement.[167] Given this background and the principle of non-appropriation principle in outer space, the common heritage of mankind concept in Moon Agreement, subsequent unilateral interpretation by certain countries that space resource extraction does not amount to appropriation, the Artemis Accords which propagate the said unilateral interpretation, the question is whether India should join the Artemis Accords.

Commentators have remarked that as Artemis Accords interpret the OST in certain way especially with regards to legality of space resource extraction and contours of non-appropriation principle, any State that joins Artemis Accords may be assumed to agree to such interpretation.[168] However, if the partners to the Artemis program are considered as equal partners, they should be able to influence the stance taken through Artemis Accords and its related instruments

163 International Lunar Research Station, ILRS, Guide for Partnership (V1.0), June 2021, online: <http://www.cnsa.gov.cn/english/n6465652/n6465653/c6812150/content.html>

164 "China Invites Venezuela to join Moon Base project", *Intersteller,* April 10 2023.

165 Russian-Chinese Joint Seminar on Cooperation in International Lunar Research Stations, online: <http://www.cnsa.gov.cn/english/n6465652/n6465653/c6812568/content.html?msclkid=793277c5c51311ecb0259d94300ba042>

166 "FACT SHEET: The United States and India – Global Leadership in Action" September 24, 2021, online < https://www.whitehouse.gov/briefing-room/statements-releases/2021/09/24/fact-sheet-the-united-states-and-india-global-leadership-in-action/>

167 NASA Office of Inspector General, "NASA's Partnerships with International Space Agencies for the Artemis Campaign", January 17, 2023, online: https://oig.nasa.gov/docs/IG-23-004.pdf.

168 Ram Jakhu, IASL-IAASS Webinar Series I Artemis Accords: Challenges & Opportunities, (Recording), online: < https://www.mcgill.ca/iasl/iasl-webinar-series/space-law-webinar-series#Artemis%20Accords>

and include concepts such as equitable benefit-sharing. It must be mentioned here that simply exchanging information by making results of scientific space missions available and creating markets for space applications are not enough for India to consider joining the initiative. India should sign such guiding principles only if it is a true cooperative effort where India has access to decision-making powers, technology transfer, and other benefits in accordance with the common benefit principle enshrined in Article 1(1) of the OST.[169] It may be mentioned here that under Article 1(1) of the OST, all States have an equal right to explore and use outer space, including Moon and other celestial bodies, and there should be equality of opportunity both for firstcomers and newcomers. As customs may being created though these Artemis Accords, signatory States should be participating in drafting of the Artemis related instruments that they sign. As NASA spokesperson said, "By bringing as many signatories onboard as early as possible, our hope is to develop a body of knowledge, informed by collective operational experiences, that will advance broader goals through established bodies such as the United Nations Committee on the Peaceful Uses of Outer Space [COPUOS]."[170]

4.2. India and ILRS

The governing principles of the ILRS initiative either has not been finalized or has not been made publicly available, though it has been stated that the governing principles will be based on equality, openness, and integrity. Whereas, India-Russia space cooperation has resulted in beneficial outcomes, there has not been any significant Sino-Indian space cooperation. Between China and India, there are territorial disputes involved leading to skirmishes at the border. Considering this and other geopolitical factors such as the Ukraine conflict, Indo-Pacific and sanctions, tying India's lunar and space future in the ILRS basket does not appear attractive. Joining ILRS initiative has certain concerns for India with China in a leadership position due to its financial and technological lead and Russia with the ongoing Ukraine war priorities contributing less. European Space Agency, which once was considering joining the ILRS, is deterred by the present geopolitical situation in Europe.[171] At this moment, considering joining the ILRS initiative is a non-starter.

5. Conclusion

India should consider joining the US-led Artemis Accords which may accelerate India's deep space exploration efforts including sending humans to Moon. However, India should become a signatory to the Artemis Accords after understanding the strengths and weaknesses of the Artemis Accords and it also should insist on equal partnership. It should also insist on inclusion of the concepts of the Moon Agreement such as equitable sharing of resources in the instruments related to Artemis Accords. It may be noted here that India has signed the Moon Agreement and though it has not ratified it, India cannot

169 Ram S Jakhu, Upasana Dasgupta and Steven Freeland, "Back to the Future: Space Law in a Networked World", 63 Proc. Int'l Inst. Space L. 443 (2020).

170 Elizabeth Howell, "Artemis Accords: Why the International Moon Exploration Framework Matters", Space.com (Aug. 25, 2022), online: https://www.space.com/artemis-accords-moon-space-exploration-importance.

171 Blaine Curcio, "China's international collaboration in space: an evolving approach from the Middle Kingdom" ROOM (2022) 1:31, online: https://room.eu.com/article/chinas-international-collaboration-in-space-an-evolving-approach-from-the-middle-kingdom

legally carry out acts that defeat its object and purpose.[172]

That said, one must acknowledge that there is no substitute for multilateralism especially under the aegis of the United Nations, despite the process being time-taking. While India should incorporate the lessons learnt from the Artemis and ILRS initiatives in the future multilateral efforts, India's signing of the Artemis Accords should be without any prejudice to its negotiating and entering into similar initiatives, multilateral or otherwise. In fact, India should make its stance clear while signing the Artemis Accords and this 'without prejudice' clause should form part of the other instruments related to the Artemis Accords. Hence, while India may consider signing the Artemis Accords, it should encourage and insist on a United Nations led initiative for lunar exploration, preferably under the Moon Agreement.

172 According to the Vienna Convention on the Law of Treaties 1969, which lays down the rules governing treaties between States, "a State is obliged to refrain from acts which would defeat the object and purpose of a treaty when (A) it has signed the treaty…". Vienna Convention on the Law of Treaties, 23 May 1969, Article 18, online: <https://legal.un.org/ilc/texts/instruments/english/conventions/1_1_1969.pdf>

Conclusion and Recommendation

V. Siddhartha*

India has a mature civilian space program whose applications have benefitted the country's development and societal goals, as also served some dual-purpose requirements. The development of heavy-lift launch vehicles has enabled exploration of space beyond earth orbit. The earlier limitations of capacity to grow and extend activities – despite inhouse development of technological capabilities over a long time – are now sought to be addressed by extensive participation of the private sector in ISRO's own missions, as also in those which are being chaperoned by it. An example of the latter is "TeamIndus", which was a participant in the Google Lunar X prize competition and was one of the five finalists (TeamIndus had won a prize of $ one million in 2015 but dropped out of the competition in January 2018 citing its inability to meet the 31 March, 2018 competition deadline. Google also cancelled the competition as it felt that the other finalists would not meet the deadline).

India's known and demonstrated capabilities can well be collaboratively harnessed by other space powers in their forthcoming planned lunar, asteroid and other deep space missions. For example, India is fully capable of providing orbital, lander and rover segments of missions similar to the Hakuto/SLIM/Peregrine/LUPEX, and The Republic of Korea's 'Danuri' follow-up. Conversely, Japan has recently enabled India to procure some specialised space application components from Japanese companies.

As established in the previous Chapters, India now has both the capabilities and capacities to plan and programme activities that establish her identity-presence on the moon, and also be a stakeholder in frequent visitation, habitation, exploration and resource utilization as contributory to India's international prestige generally, and in Space in particular.

Notwithstanding such 'Atmanirbharta' in Space, it should be hoped that by the end of the decade, geopolitics on Earth would have matured to the point where international collaborative efforts amongst space-faring powers would be the preferred norm – independent of these powers' technological capability or affordability to "go-it-alone" to the Moon or Mars. India should certainly advocate such a course, perhaps even enshrine it in new international arrangements that have the force of a new inclusionary Moon Treaty to replace the current one.

Post Artemis Accord initiatives: In the above context, it should be noted that even as India and twenty-six other countries have signed the Artemis Accords, the Lunar Gateway and other elements of the Artemis Missions are still work in

* Adjunct Faculty, ISSSP, National Institute of Advanced Studies, Bengaluru

progress. *It would thus be wise for India to engage right-away in in-country exercises to map-into our international collaborative programmes the philosophy expressed in the foregoing paragraph.* Such a deeply structured 'techno-diplomatic' engagement should enable India to shape with persuasive analytical rigour the NASA's own "Artemis" programme so as to incorporate substantively the above philosophy. India will then be in a position to build on its capabilities, contribute to overall knowledge generation in space beyond Earth orbit and, in the process, accelerate the development of her own missions with such independent elements as serve her own programmes of off-Earth space exploration, inviting NASA - and others - to partner in those latter.

Even as we are now a partner in NASA's Artemis programme, the above approach to medium- and long-term lunar (and planetary) exploration, if adopted, will call for a substantive engagement on the aims, objects and modalities of fashioning the Artemis programme itself, not only with NASA, but also directly with its other Artemis partners. Such a dialogue is strongly advocated, as it opens up opportunities for expanded Space partnerships directly with other space-faring nations, with an added focus on Asian Countries, such as Japan and South Korea, who seek to enhance their autonomous presence in Space.

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Author's Bio

BR Guruprasad

BR Guruprasad has worked in the Indian Space Research Organisation (ISRO) for nearly 37 years and superannuated in May 2020 as Scientist 'SG'/ Associate Director, Office of Media and Public Relations, ISRO Headquarters. As a satellite scientist, has rich experience in Satellite Mission Planning, Analysis and Operations and worked for over 25 Indian Satellite Missions at ISRO Satellite Centre (now U R Rao Satellite Centre). He has worked at German Space Agency DLR and at NASA. He is serving as an Adjunct Faculty Member at the National Institute of Advanced Studies (NIAS), Bengaluru. Serving on the editorial board member of the Journal of Aerospace Sciences and Technologies. Obtained Doctor of Philosophy (PhD) from Mysore University for the Thesis work "Contribution of External and Indigenous Technological Elements to India's space Capabilities.

Rajaram Nagappa

Rajaram Nagappa has been associated with the International Strategic and Security Studies Programme since 2007 and has worked on missiles, space weapons and space security issues. His recent works include India and Weaponization of Space and Ballistic Missile Defence capability in India, which have appeared in the Report of the International Working Group on Missile Defence Systems and Weapons in Space. He has carried out studies on hypersonic weapon systems and is co-author of the monograph "Underwater Domain Awareness - case for India".

Amit Mukherjee

Amit Mukherjee is an Assistant Professor in the International Strategic Security Studies Program at the School of Conflict and Security Studies in National Institute of Advanced Studies, Bangalore. His work involves use of GIS and Remote Sensing systems for national and international security. He has a PhD on, "Application of GIS for India's Defence: To assess battlefield conditions and its effects on weapons and weapons systems". Apart from this, he has a Masters in Computer Science. He was also a Post-Doctoral Fellow (2013-2016), at National Security Studies Center, University of Haifa, Israel. His areas of research interest include homeland security, counter insurgency, terrorism studies, maritime security, weapons and warfare, military affairs and strategy, border security, and India-Israel Security Cooperation.

Upasana Dasgupta

Upasana Dasgupta is an Assistant Professor, Jindal Global Law School, O.P. Jindal Global University. She holds DCL (PhD) from Institute of Air and Space Law , McGill University, which she pursued as an Erin J C Arsenault Fellow. She wrote her doctoral thesis titled "Preventing collisions between space objects in outer space: Clarifying the law of state responsibility for better enforcement". She also pursued LLM (Air and Space Law) from McGill University and was awarded Nicolas Mateesco Matte Prize for highest marks in space law. Upasana's research interests include international space law, public international air law, public international law, international legal theory, and legal education.

V. Siddhartha

V. Siddhartha is an Adjunct Faculty, ISSSP, NIAS. V. Siddhartha served during 2007-09 on invitation of the Secretary General of the United Nations as a member of the Experts Group in New York of the Committee on UN Security Council Resolution 1540. Upon returning, V. Siddhartha served in 2009-10 with the Principal Scientific Adviser to the Government of India as Scientific Consultant (Advanced Technologies). He was an Emeritus Scientist in DRDO. V. Siddhartha has twice been Consultant to the Ministry of External Affairs, Government of India, on export control and S&T issues in international security, and on the Indian WMD Act, 2005. V. Siddhartha served for some time as Secretary of the Science Advisory Council to the Prime Minister. He was a Distinguished Fellow during 2010-12 in the Centre for Air Power Studies, New Delhi.

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11 **Abstract:**

The lunar missions gained impetus in the 21st century after decades of lull. The newer sprite in lunar missions began with orbiter and impact missions, which included India's moon -impact probe onboard the Chandrayaan 1, in 2008. Subsequent robotic missions included orbiters, landers and rovers as well as sample collection missions. The Lunar south polar regions which is under permanent shadow is expected to have reserves of water-ice, essential for lunar habitation and as a source for future deep space missions(space) operating from lunar surface. Other Lunar resources include helium 3 a potential source for nuclear fusion reactors and other minerals which can be commercially exploited and in-situ resource utilization. Consequently, number of countries, space agencies and private parties are keen on lunar exploration. This report details the lunar explorations carried out and being planned, the initiatives taken by leading space faring countries and the technological aspects of lunar exploration. The role of international cooperation is emphasized.

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