Outer Space Institute Report

New Moon: A Cislunar Security Workshop Report

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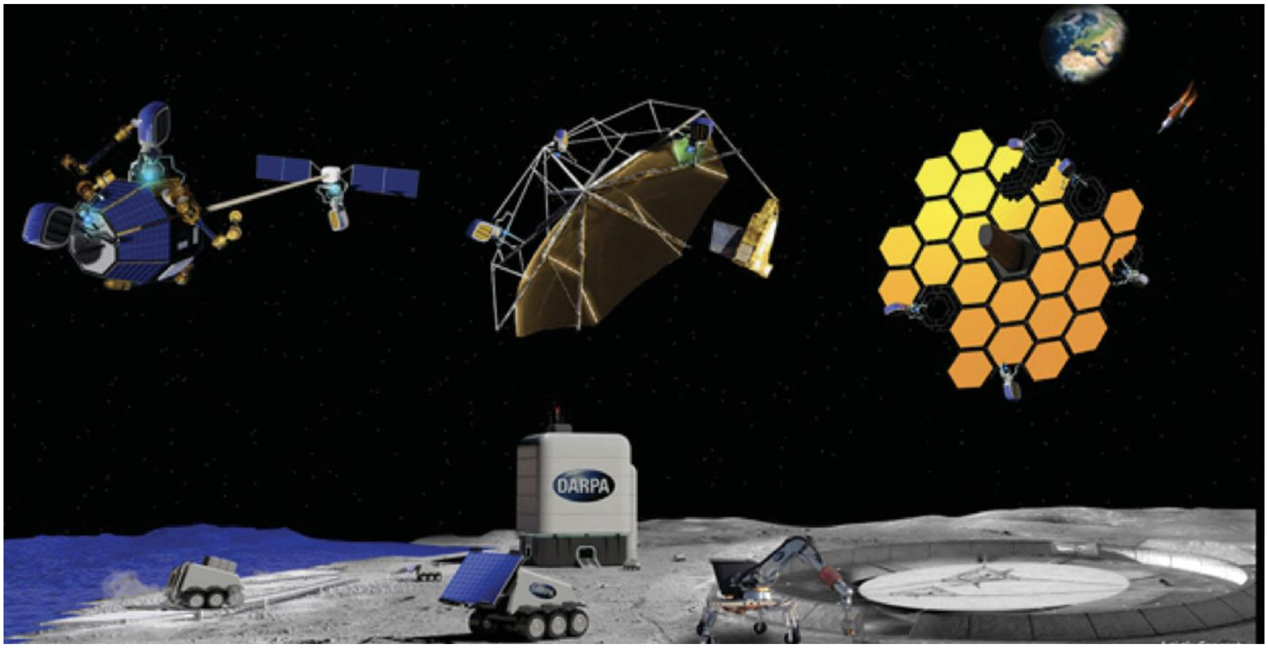
A Space Security Network Initiative



Artist's illustration of plans for a DARPA program to develop technologies for building structures in orbit and on the Moon. Image courtesy of Darpa.mil according to the DARPA User Agreement (www.darpa.mil/policy/usage-policy).

Preamble

On March 1 and 2, 2024, experts from a variety of backgrounds, disciplines, and countries gathered on Salt Spring Island, British Columbia, Canada, to discuss existing and foreseeable security-related challenges arising from activities on-and-around the Moon.

The workshop and the accompanying research, analysis, and consultations were conducted by the Space Security Network (SSN) and the Outer Space Institute (OSI). The SSN is based in Vancouver at the University of British Columbia and supported by an arms-length grant from the Canadian Department of National Defence's Mobilizing Insights in Defence and Security (MINDS) program. The OSI is a global network of researchers united by their commitment to transdisciplinary research addressing grand challenges facing humanity's use and exploration of outer space.

The workshop concluded with the adoption of the "Moby's Recommendations on Lunar and Cislunar Security", which are named after one of the workshop dinner venues. The intended audience for the recommendations is broad, and includes governments, industry, and inter-governmental and nongovernmental organizations. The recommendations are reproduced at the end of this report.

1. INTRODUCTION

1.1. Definitions

Cislunar Space – The volume extending from Earth's geosynchronous orbits and encompassing the Moon, the Moon's orbits, the Earth–Moon Lagrange points, and certain types of transfer orbits. Some definitions of cislunar space include Earth orbits.

Lunar Lagrange Points ('L points') – Locations where the combined gravitational acceleration due to the Earth and the Moon allows a small object, such as a spacecraft, to orbit the Earth at the same rate as the Moon.

Lunar Regolith – A layer of loose rock and dust, resulting from eons of bombardment by micrometeoroids and energic particles, that covers the entire surface of the Moon. The dust is made up of fine particulates that are jagged and very sharp.

Space Situational Awareness (SSA) and Space Domain Awareness (SDA) – These terms are often used interchangeably. However, SSA is focused on observing and cataloguing space objects, while SDA involves additional steps of predicting, characterizing, and understanding the evolution of the space environment.

Security Dilemma – Arises when a state lacking clear information about a potential adversary's military activities must choose between building up its own military, or doing nothing and risk being overwhelmed.

1.2. Canada's interests

Canada has multiple interests in cislunar space. One is part of a broader concern for international peace and security, which would only benefit from preventing an arms race in space. Another is the Canadian Space Agency's partnership in the Artemis Program, which includes the provision of a robotic arm for the Lunar Gateway space station. A further interest is fostering greater domestic space industry capacity, as symbolized by the Lunar Exploration Acceleration Program and the Canadian Lunar Rover, to be constructed and operated by the Canadian company Canadensys.

1.3. Major changes underway

Lunar and cislunar activities are rapidly expanding, driven by at least three factors:

(1) States are building their capacity for exploration, science, and long-term human habitation beyond low Earth orbit (LEO)
(2) States are competing with each other, and at least some of this competition is driven by suspicion
(3) Globally, the space economy is growing quickly

Together, these factors create a situation that is leading to:

(1) Increased numbers of state and non-state actors accessing the Moon
(2) Increased interest in space situational awareness and space domain awareness on-and-around the Moon
(3) Plans for military spacecraft in cislunar space
(4) Intensified diplomacy on the legal conditions for space resource extraction and use

1.4. Recent lunar missions

Although the Moon is being accessed by more actors than ever before, lunar operations remain challenging. China has made substantial progress recently with its robotic Chang'e program, including placing rovers on the lunar surface, conducting a lunar sample return mission, and operating spacecraft in Lunar Lagrange points for communication purposes. India has successfully landed and operated a rover, as has Japan. The US successfully flew its Artemis I uncrewed test mission with NASA's new rocket (Space Launch System) around the Moon, although follow-up crewed missions have been delayed. Russia,[1] the US,[2] Japan,[3] and Israel[4] have all seen failed robotic landing attempts, with the latter three missions led by private companies. The most recent attempt by a US company, in February 2024, saw the spacecraft require the emergency use of a NASA navigation system before tipping over during landing.

1.5. Future lunar missions

According to James Myers of The Aerospace Corporation: "In the United States alone, at least 10 federal organizations and more than 70 commercial companies are already investing in cislunar capabilities, with new players and objectives emerging daily."[5]

The US activity is centred on the Artemis Program, which involves both traditional NASA partners such as Canada, Japan, and the member states of the European Space Agency, as well as a larger circle of states – 52 of them as of December 2024 – that have endorsed the legally non-binding Artemis Accords. An important part of the Artemis Program involves the distribution of numerous contracts to private companies, including for rockets and landers capable of delivering cargo and supplies to the surface of the Moon.

Meanwhile, China has signed agreements with eight countries on the construction of an "International Lunar Research Station".

[1] Reuters, "Russia pinpoints cause of moon shot failure, looks to bring next missions forward," 3 October 2023, at: https://www.reuters.com/world/europe/russia-says-moon-shot-failed-due-control-unit-malfunction-2023-10-03
[2] Jonathan Amos, "Peregrine lander: American Moon mission destroyed over Pacific Ocean," BBC News, 18 January 2024, at: https://www.bbc.com/news/science-environment-67962397
[3] Jeff Foust, "Software problem blamed for ispace lunar lander crash," SpaceNews, 26 May 2023, at: https://spacenews.com/software-problem-blamed-for-ispace-lunar-lander-crash/
[4] Daniel Oberhaus, "A Crashed Israeli Lunar Lander Spilled Tardigrades on the Moon," Wired, 5 August 2019, at: https://www.wired.com/story/a-crashed-israeli-lunar-lander-spilled-tardigrades-on-the-moon/
[5] James Myers, "U.S. leadership of cislunar space hinges on foresight and planning," SpaceNews, 12 April, 2023, at: https://spacenews.com/op-ed-u-s-leadership-of-cislunar-space-hinges-on-foresight-and-planning/

1.6. Concerns about China

Proponents for the development of US military capabilities in cislunar space point to the rapid growth in commercial activity on the Moon, arguing that mining and other operations will need protection from foreign interference. Connected to this is the perception that, in the absence of US military involvement, other states, especially China, might develop superior capabilities and even a dominant presence – perhaps leading to the exclusion of the US and its allies from cislunar space. The successes of the Chang'e program and plans for an "International Lunar Research Station" are cited as evidence of hostile intent. So, too, is China's behaviour on Earth's surface, especially in the South China Sea.

1.7. Security dilemmas

The concerns about China described in the previous paragraph could easily give rise to a "security dilemma", whereby a state lacking clear information about a potential adversary's military activities must choose between building up its own military, or doing nothing and risk being overwhelmed. Any buildup in response to another state's actions, whether based on correct or incorrect information, can prompt that other state to begin (or accelerate) its own buildup, spiraling into an arms race. In the context of cislunar space, a security dilemma would increase the risk of conflict in space, and perhaps even on Earth through cross-domain responses. At a minimum, a security dilemma could limit or deny new opportunities for science and economic development.

When discussing about a possible cislunar security dilemma in the US, it is important to note that a similar security dilemma could also be developing in China. Indeed, it is the nature of security dilemmas to feed off each other. Fortunately, humanity remains in the early stages of cislunar development, making it possible to steer a course that preserves the peaceful exploration and use of outer space, even with many state and private actors competing. Finding that course will require a concerted effort to understand non-US perspectives, including by engaging with Chinese and other international experts.

1.8. Literature on cislunar security

Most of the published material on cislunar security in the English language falls into two groups:

(1) Documents produced by Western militaries or military-associated think tanks that reinforce the perception of cislunar space as a contested region. Most call for increased funding for the development of military capabilities.

(2) Media reports, often based on interviews with Western military leaders and military-associated think tanks, that reinforce the perception of cislunar space as a contested region.

Only a few experts, notably Jessy Kate Schingler, Victoria Samson, and Nivedita Raju,[6] have recommended a more cautious approach. Key points from their 2022 article are summarized below.

Separately, the American Institute of Aeronautics and Astronautics (AIAA) has formed a Cislunar Ecosystem Task Force involving industry, government, and academia to integrate planning for cislunar space. Initially, the Task Force will focus on communications, power, and transportation infrastructure.[7] There is also the International Astronomical Union (IAU) commission working group on “Astronomy from the Moon”.[8] While its focus is on preserving the ability to conduct astronomical observations from the Moon across the electromagnetic spectrum, it is fundamentally concerned about the need for coordination among all actors on-and-around the Moon.

Yet there has been little effort by Western experts to analyze documents on cislunar space from China or, indeed, to engage with Chinese experts. Unfortunately, this only increases the risk of one or more security dilemmas.

2. UNDERSTANDING THE EARTH-MOON SYSTEM

Good decision-making requires a strong understanding of context. In the case of cislunar security, this means that the unusual characteristics of the Moon and its orbital environment must be understood.

2.1. The Moon

The Moon is tidally locked to Earth: its rotation is commensurate with its orbit and the same side of the Moon, the ‘near side’, always faces Earth. Over time, approximately 60 percent of the Moon can be seen from Earth due to a combination of apparent and physical ‘libration’, i.e., the rocking of the Moon in its orbit. The other 40 percent, comprising most of the lunar ‘far side’, is only known through spacecraft and rovers. Moreover, the approximately 10 percent of the far side that can in principle be seen from Earth is at a high angle of incidence, providing limited information.

The near side contains most of the lunar maria (‘seas’), which are basalt plains formed from volcanic flooding of low-lying areas, including impact basins. These are surrounded by highlands of anorthosite rocks, which are thought to be some of the first rocks to crystalize from the lunar magma ocean, and represent the oldest regions on the Moon.[9] The maria are thus younger than the

[6] Jessy Kate Schingler, Victoria Samson, and Nivedita Raju, “Don’t Delay Getting Serious About Cislunar Security,” War on the Rocks, 6 July 2022, https://warontherocks.com/2022/07/dont-delay-getting-serious-about-cislunar-security/

[7] James Myers, 12 April 2023, at: https://spacenews.com/op-ed-u-s-leadership-of-cislunar-space-hinges-on-foresight-and-planning/

[8] International Astronomical Union Working Groups, at: https://www.iau.org/science/scientific_bodies/working_groups/

[9] Marc D. Norman et al., “Chronology, geochemistry, and petrology of a ferroan noritic anorthosite clast from Descartes breccia 67215: Clues to the age, origin, structure, and impact history of the lunar crust," (2003) 38.4 *Meteoritics & Planetary Science* 645-661, at: https://onlinelibrary.wiley.com/doi/10.1111/j.1945-5100.2003.tb00031.x

lunar highlands (roughly between 3.1 and 3.9 billion years or so for the maria compared with around 4 billion years and older for the highlands).[10]

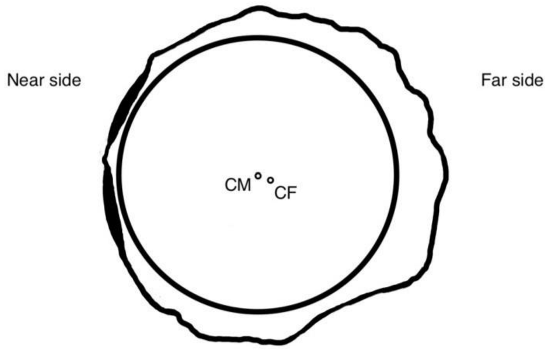


Figure 1: Schematic of the Moon's crustal differences, as well as the offset between the centre of mass (CM) and the centre of figure (CF). The dark regions are representative of maria on the lunar near side. The diagram is intended to be illustrative only. The Aitken basin is crudely represented by the thinner crust along the south lunar far side.

The far side contains few maria, and has a thicker planetary[11] crust than the near side. Both sides are heavily cratered – as a result of asteroid impacts – with variations in crater density due to surface ages (a younger surface has fewer craters). The Aitken basin, located on the far side and extending to the southern lunar pole, is among the largest impact basins in the Solar System and is a region of high scientific and exploration interest.

The entire Moon is covered in a layer of loose rock and dust called regolith, formed by eons of bombardment by micrometeoroids and energic particles. The dust is made up of fine particulates that are jagged and very sharp. As a consequence, it is an operational and health hazard due to its infiltration into equipment and the potential for respiratory illness in astronauts. But if the risks from dust can be managed, the regolith has many potential uses, from construction to science to resource extraction, including oxygen and water.

One often-discussed resource is helium-3, a fusion product produced in the Sun and embedded in the lunar regolith through the solar wind.[12] But while using helium-3 for further fusion reactions could provide an important energy source, this may require unrealistic amounts of regolith mining.

Lunar dust is naturally lofted through bombardment of meteoroids and separately through electrical charges. Much of this dust remains close to the surface, since the Moon's surface has an escape speed of about 2.4 km/s,[13] but lunar dust fountains can still transport dust over great distances and form a lunar dust exosphere.[14] One thing is clear: Dust is always moving on the Moon, despite it being an airless world, and human activity could enhance this natural process,

[10] "Lunar Maria", in Encyclopedia of Physical Science and Technology (Third Edition), 2003, at: https://www.sciencedirect.com/topics/physics-and-astronomy/lunar-maria

[11] While the Moon is not a planet under the IAU definition of a planet, it is a type of planetary body and a key object for comparative planetology of terrestrial worlds.

[12] European Space Agency, "Helium-3 mining on the lunar surface," at: https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Space_for_Earth/Energy/Helium-3_mining_on_the_lunar_surface; Mark R. Whittington, "China has returned helium-3 from the moon, opening door to future technology," The Hill, 18 September 2022, at: https://thehill.com/opinion/technology/3647216-china-has-returned-helium-3-from-the-moon-opening-door-to-future-technology/

[13] The Moon is roughly a quarter of Earth's size and 1/81 of its mass.

[14] Lianghai Xie et al., "Lunar dust fountain observed near twilight craters." (2020) 47(23) *Geophysical Research Letters* e2020GL089593, at: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020GL089593

particularly through repeated landings and launches from the surface.[15] Mining could further enhance the dust exosphere through secondary interactions, depending on the extent of mining and the methods used.

2.2. The lunar orbital environment

2.2.1. Moon-centred orbits

The lunar orbital environment presents both challenges and opportunities. One major challenge is that many selenocentric (Moon-centred) orbits are not long-term stable. Objects in orbit about a symmetric sphere of mass follow very well-behaved elliptical orbits, and will stay on those orbits unless influenced by separate forces – regardless of how the mass is distributed in radius. The Moon, however, has many 'mascons' (mass concentrations) that are asymmetrically distributed throughout it, creating a gravitational field that is consequentially different from a symmetrical, spherical mass. One such consequence is that orbital eccentricities – a measure of an orbit's ellipticity – vary substantially and over time could often cause objects to crash into the lunar surface at speeds over 1 km/s (3600 km/hr).

This situation raises several considerations, including:

(1) It will be difficult to use the thin orbital shells about the Moon for satellite constellations or lunar space traffic management

(2) Debris and derelict spacecraft will crash into the lunar surface unless careful steps are taken to avoid this outcome. Unlike reentering space objects on Earth, objects de-orbiting on the Moon will not burn up or slow down during an atmospheric reentry, since the Moon has only the most tenuous of atmospheres

(3) The lunar orbital regions that are long-term stable are a finite resource, and therefore very desirable. Congestion could easily become a problem, and with that, the risk of collisions

2.2.2. Lagrange Points

There is also an entirely different set of orbits that needs to be considered, arising from the three-body nature of the cislunar environment (Earth, Moon, and spacecraft). Principal among these are orbits that make use of the lunar Lagrange points.

Lunar Lagrange points, or L points, are locations where the combined gravitational acceleration due to the Earth and the Moon allows a small object, such as a spacecraft, to orbit the Earth at the same rate as the Moon (see Figure 2). Due to these unique features, L points will be important for future lunar activities as locations where communications and monitoring equipment, refueling depots and even space stations can be maintained at relatively low energy output.

[15] Philip T. Metzger, "Dust transport and its effect due to landing spacecraft," in (2020) 2141 *The Impact of Lunar Dust on Human Exploration* 5040, at https://www.hou.usra.edu/meetings/lunardust2020/pdf/5040.pdf

In practice, L points may be better thought of as regions of space relative to the Moon rather than fixed points, as objects placed at these locations will not stay there in general. Indeed, the co-linear L points (L1-L3) are dynamically unstable – like a pencil placed perfectly on its point, the slightest perturbation will cause it to move away, making station-keeping a necessity. The points L4 and L5 are different, as the Coriolis effect stabilizes orbits in these regions. But even so, objects will not remain fixed and will instead 'orbit' (really a type of libration) about these L points when viewed in a frame rotating with the Moon. This can offer advantages for monitoring the Moon, although it must be appreciated that the distance from L4 to the Moon is essentially the same as the distance from the Earth to the Moon. That said, these "Lyapunov orbits" can be very large, with close approaches to the Moon itself.

2.2.3. Halo, Lissajous, and transfer orbits

Halo and Lissajous orbits are a class of orbits that take advantage of properties of three-body dynamics, with periodic or quasiperiodic orbits about the unstable L1 and L2 points (see Figures 3-6) being of keen interest. Essentially, in the rotating frame, these types of orbits will appear to oscillate around L1 or L2 (or L3) guided by relatively small amounts of thruster use for station-keeping. The oscillations can be quite large and perpendicular to the Moon's orbital plane.

Other types of halo orbits are possible, too, such as the near-rectilinear halo orbit that will be used for the Lunar Gateway space station. Such an orbit will have a very close approach to the Moon (perilune) followed by a very wide distance from the Moon (apolune). It is also an orbit made possible through three-body interactions and requires only small amounts of station-keeping.

Then there are transfer orbits. These, as the name suggests, are orbits between bodies, such as the Earth and the Moon, or regions of cislunar space, such as between different L-points. They may pass through many regions of the cislunar environment to complete the transfer, including close approaches to either the Earth or the Moon or both.

Transfer orbits could involve common bottlenecks. However, these bottlenecks do not offer much in the way of military advantage. They pose a different kind of threat, in that they require coordination and care when disposing of debris, including defunct spacecraft, which can last for a long time in the cislunar environment. Something abandoned in one area of cislunar space could eventually strike the Moon, break up into debris streams, confound scientific studies,[16] or interfere with other activities.

2.2.4. Practical implications of the lunar orbital environment

Connecting all these orbits helps to develop a picture of potential cislunar operations, as well as options for cislunar situational-and-domain awareness. L1 and L2 points allow continuous monitoring of the Moon, with L2 giving far side coverage, while also enabling communications with Earth. Operations involving other L points could enable long-lived monitoring of the Moon and Earth, although at large distances. However:

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[16] Tereza Pultarova, "The oldest gamma-ray burst ever discovered was just a piece of space junk," SPACE.com, 7 October 2021, at: https://www.space.com/oldest-gamma-ray-burst-space-junk-mistake

(1) Any type of close inspection of objects in L points will be tremendously difficult, though not impossible, owing to the vast volumes of space that a spacecraft could encounter

(2) The widespread concern that L points could be occupied by other space actors is, in fact, false

Misconceptions concerning the physical constraints of cislunar space can exacerbate suspicions between states and create complications for space operators. It is crucial that policy makers seek out, include, and listen to experts in the orbital dynamics of cislunar space.

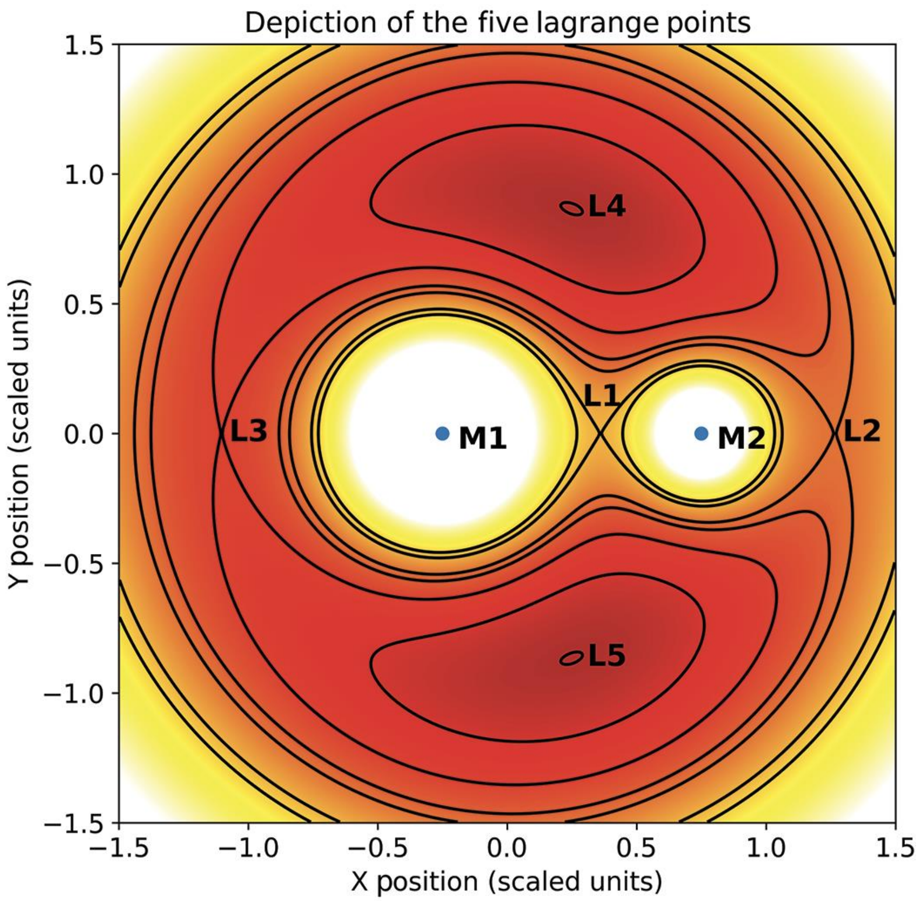

Figure 2. A depiction of the Lagrange points for a simple dynamical model involving two massive bodies (M1 > M2), such as the Earth and the Moon. The curves and colours represent constraints on the motion of a third essentially (i.e. by comparison) 'massless' body, such as a spacecraft. The image itself is in the 'rotating frame'; that is, M1 and M2 appear to be stationary even though they are orbiting each other about their centre of mass. X marks the spot for the L1, L2 and L3 Lagrange points. L4 and L5 are shown as the darker 'islands' on the plot. An object at exactly those points will appear to be stationary in this rotating frame. In practice, the objects are placed on orbits that oscillate about the L points. This example sets M2 to be one third the mass of M1 to accentuate the structure (the actual Moon-to-Earth mass ratio is about one to 81).

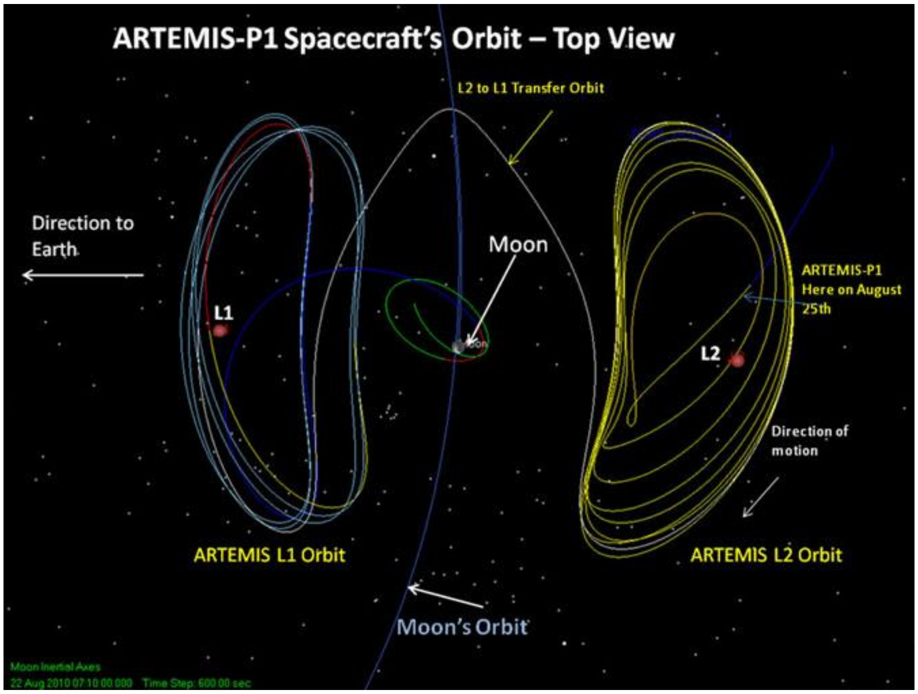

Figure 3. Artist's depiction of halo orbits about the L1 and L2 points, including a transfer from one Lagrange point to another. The orbits are shown in a frame that moves with the Moon. Credit: NASA/Goddard

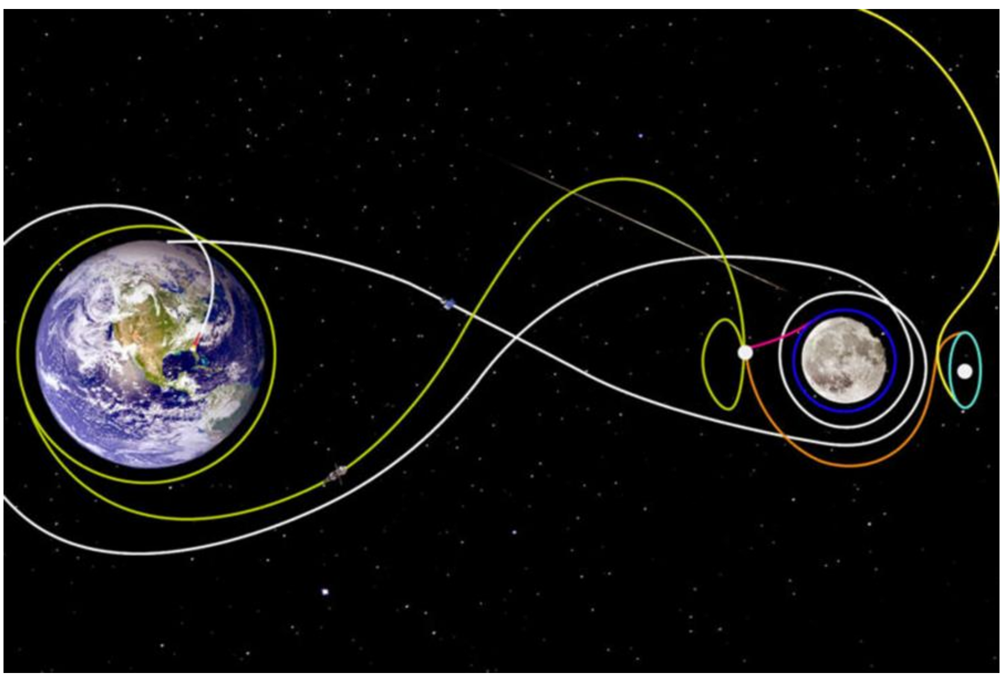

Figure 4. Transfer orbits throughout the cislunar environment, including an Earth-Moon transfer with Earth return, transfer to selenocentric orbits, halo orbits about the L1 and L2 points, and transfer between them, as well as to L4. Credit: K. Howell and C. Frueh/cislunar space dashboard/Purdue University.

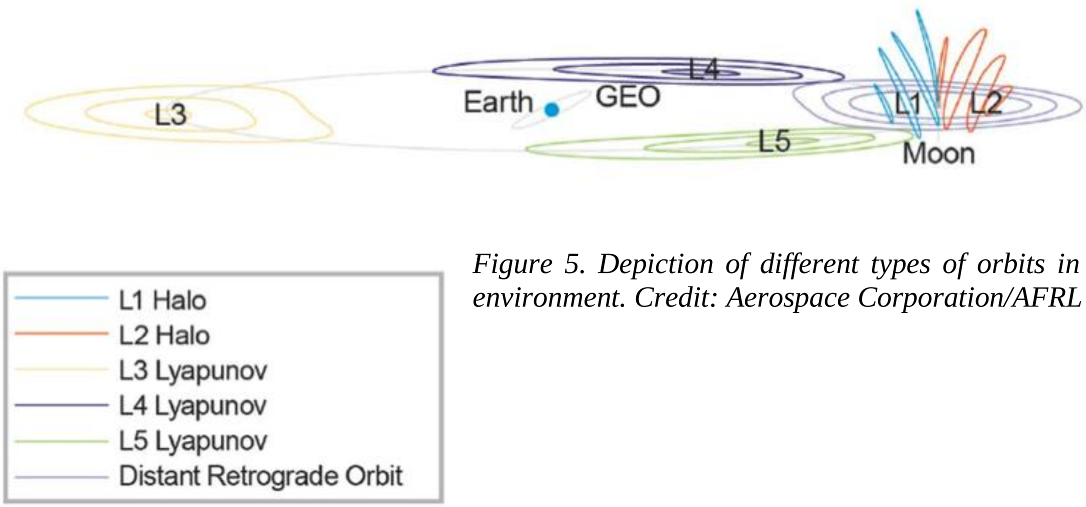

Figure 5. Depiction of different types of orbits in the cislunar environment. Credit: Aerospace Corporation/AFRL 2021-1271

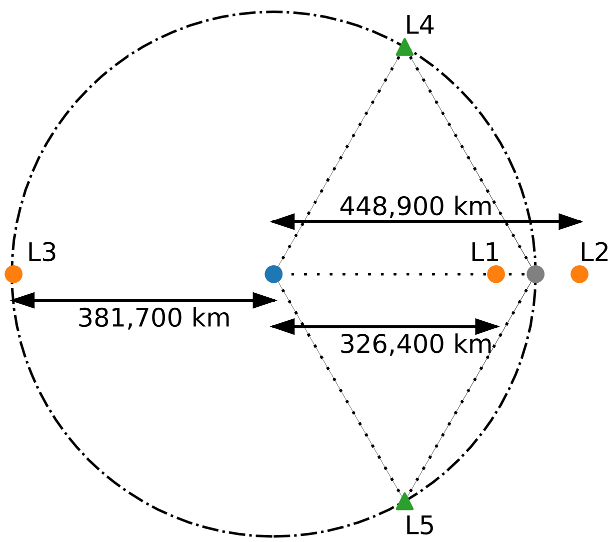

Figure 6. View of the cislunar environment and Lagrange points under the circular, restricted three-body approximation, which preserves most of the important properties of the cislunar environment. The Earth (blue) is at the centre of the diagram and the Moon (grey) sits on the dotted-dashed circle. The dotted lines represent a distance of 384,400 km, which is also the circle's radius. The Earth-Moon-L4/L5 triangles are equilateral. Here, the Moon is envisaged to orbit Earth in a counter-clockwise direction following the large circle, with all Lagrange points rotating to maintain the same relative Earth-Moon position.

3. SECURITY DILEMMA

3.1. Factors contributing to a security dilemma

A security dilemma occurs when a state, lacking clear information about whether a potential adversary is engaged in a military buildup, faces a choice between building up its own military, or doing nothing and risk being overwhelmed. Frequently cited examples of security dilemmas include Germany's naval buildup prior to World War I, and the nuclear arms race between the US and the USSR during the Cold War.

On-and-around the Moon, the potential for a security dilemma is heightened by the physical challenges of monitoring cislunar space. The three-body interactions between a spacecraft, the Moon, and Earth cause orbits to follow paths that are very different from those about the Earth, with other effects such as radiation pressure only increasing the difficulty. While orbits remain predictable in the sense that they can be propagated forward (or backward) in time, even small uncertainties can lead to large discrepancies in the actual orbital evolution.

Although uncertainties are a challenge for Earth orbits, too, especially those affected by atmospheric drag, a combination of optical observations and radar can constantly update orbital databases. At the moment, there is no equivalent infrastructure for doing this in the cislunar environment, in large part because, as Figures 3-6 show, the distances and volumes involved are so vast.

Earth-based infrastructure cannot do the job. Radar returns fall off as the inverse distance to the fourth power – an inverse square law to the object and an inverse square law back. Optical observations fall off as only the inverse square law, as the distance from the Sun remains essentially unchanged, but the objects will be challenging to detect nonetheless, unless they are very large (see Figure 7).

Different strategies are needed, including developing some kinds of capabilities in cislunar space sooner rather than later. As Schingler, Samson, and Raju explained: "We lack situational awareness and effective frameworks for reasoning about this domain. We need new tools to help us understand this emerging landscape, lest perceptions become distorted, increasing the risk of conflict."[17]

Some states already have plans for cislunar situational-and-domain awareness. But here, an additional complication arises, in the form of spacecraft that can be perceived as dual-use. Schingler, Samson, and Raju gave the example of CAPSTONE mission, a CubeSat built by a US company, paid for by NASA, and launched from New Zealand in 2022. They explained that, while CAPSTONE's "primary mission is to study the orbit being planned for NASA's Lunar Gateway,

[17] Schingler, Samson, and Raju, op cit.

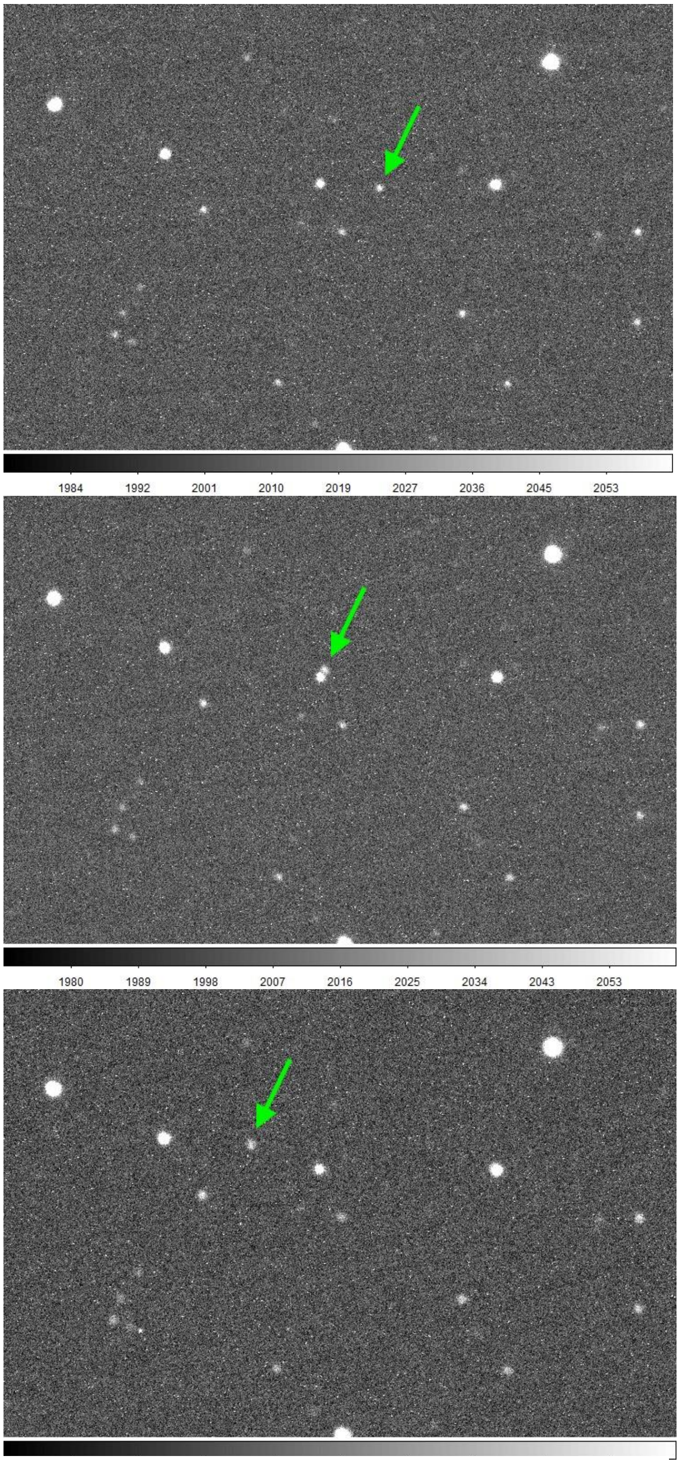

Figure 7: JWST imaged by the UBC Southern Observatory, Thunderbird South. JWST is in the Earth-Sun L2 point, which is about 4 times farther from Earth than the Moon. Credit: Sean Heakes and Chantal Hemmann, UBC undergraduates.

the operator Advanced Space also signed a data sharing agreement with the U.S. Air Force. In this environment, a lack of coordination and transparency provides ever-more opportunities to project our greatest fears into the void."[18]

There is now, as Schingler, Samson, and Raju further explained, "a small but vocal contingent in U.S. national security circles arguing that the U.S. Space Force should have some sort of cislunar military presence, if only to protect commercial interests."[19]

This view is further amplified by a lack of engagement with Chinese language documents as well as Chinese experts. In the US, part of the reason for this is the 2011 Wolf Amendment, whereby Congress prohibited NASA from using government funds to engage in direct, bilateral cooperation with China or any Chinese-owned company – unless Congress has given its specific approval. As Leonard David explains: "Ever since, a potential repeal of the amendment has been a political football, tossed between hawkish factions eager to paint China as an emerging adversary in space and less combative advocates wishing to leverage the country's meteoric rise in that area to benefit the U.S."[20] That said, NASA has sought and received waivers from Congress on several occasions to enable some focused cooperation with the China National Space Administration (CNSA).

These arguments for a military presence in cislunar space are now translating into realities, with the Space Force expressing three cislunar development priorities:

[18] Schingler, Samson, and Raju, op cit.
[19] Schingler, Samson, and Raju, op cit.
[20] Leonard David, "Can the U.S. and China Cooperate in Space?" Scientific American, 2 August 2021, at: https://www.scientificamerican.com/article/can-the-u-s-and-china-cooperate-in-space/

(1) Space domain awareness
(2) Communications
(3) Positioning, navigation and timing (PNT)[21]

In April 2022, the Space Force created the 19th Space Defense Squadron to monitor cislunar space.[22] There are also a number of projects underway that aim to develop and deploy military spacecraft into the region.

3.2. Air Force Research Laboratory

The US military is also developing its own spacecraft for use in cislunar space. The Air Force Research Laboratory (ARFL) is preparing the **Oracle (previously named the Cislunar Highway Patrol Satellite, CHPS)**, which will be placed at one of the L points to track other spacecraft in cislunar space and lunar orbits.[23] In November 2022, a US $72 million contract was awarded to the company Advanced Space to build the spacecraft.[24]

The AFRL is also developing the **Defense Deep Space Sentinel (D2S2)**, which is described as a highly maneuverable spacecraft able to conduct "rendezvous/proximity operations" as well as "space object removal and recovery, and other applications in defensive space operations".[25]

Arguably, any improved situational or domain awareness in cislunar space is a good thing, providing more information as to what other space actors are doing, and what they are not. But such a role could, at least for the foreseeable future, be fulfilled by civilian spacecraft. Such spacecraft could also engage in scientific studies, including detecting and tracking asteroids and comets for the purposes of planetary defence.

As for D2S2, there is nothing inherently wrong with space debris removal and recovery technology. The problem is that such technology is inherently 'dual-use' and could be perceived as a threat to other spacecraft, thus feeding the security dilemma. For this reason, the daunting task of cleaning up space debris should be led by national space agencies. D2S2 is also suspect because there is no current need for debris removal in cislunar space, and unlikely to be any such need for decades to come. The situation in LEO is different.

[21] Theresa Hitchens, " 'Critically important': New White House strategy for cislunar research echoes Space Force," Breaking Defense, 17 November 2022, at: https://breakingdefense.com/2022/11/critically-important-new-white-house-strategy-for-cislunar-research-echoes-space-force/
[22] Theresa Hitchens, "To infinity and beyond: New Space Force unit to monitor 'xGEO' beyond Earth's orbit," Breaking Defense, 21 April 2022, at: https://breakingdefense.com/2022/04/to-infinity-and-beyond-new-space-force-unit-to-monitor-xgeo-beyond-earths-orbit/
[23] Theresa Hitchens, "AFRL satellite to track up to the Moon; Space Force–NASA tout cooperation," Breaking Defense, 21 September 2020, at: https://breakingdefense.com/2020/09/afrl-satellite-to-track-up-to-the-moon-space-force-nasa-tout-cooperation
[24] Theresa Hitchens, " 'Critically important': New White House strategy for cislunar research echoes Space Force," Breaking Defense, 17 November 2022, at: https://breakingdefense.com/2022/11/critically-important-new-white-house-strategy-for-cislunar-research-echoes-space-force/ . Advanced Space previously built the CAPSTONE CubeSat that was launched to the Moon, as discussed above.
[25] Theresa Hitchens, "Space Force, AFRL to demo mobile lunar spy sat," Breaking Defense (30 November 2020), at: https://breakingdefense.com/2020/11/space-force-afrl-to-demomobile-lunar-spy-sat

There are also questions to be asked concerning the destination of the debris. Where, exactly, would the debris be removed to? Should any individual state be allowed to make these decisions on its own? Answers to these questions will be required at some point, since the two other most feasible options – leaving derelict spacecraft to drift uncontrolled in cislunar space or redirecting them so that they crash into the lunar surface – are unsustainable practices. A further option, sending debris into a heliocentric (i.e., Sun-centred) orbit, might seem like a better idea but would present its own challenges, including that the debris could come back to the Earth–Moon system.[26]

3.3. Defense Advanced Research Projects Agency

The Defense Advanced Research Projects Agency (DARPA), which also falls under the US Department of Defense, has announced that it is starting up a **Novel Orbital and Moon Manufacturing, Materials and Mass-Efficient Design (NOM4D)** program, which "seeks to pioneer technologies for adaptive, off-earth manufacturing to produce large space and lunar structures."[27] According to DARPA, "The NOM4D program will pioneer new materials and manufacturing technologies for construction on orbit and on the lunar surface." Although the program does not presently include an actual military base, the announcement on DARPA's website was originally accompanied by an artist's depiction that included a sizeable building, a landing pad and at least six vehicles – with the building and one of the vehicles sporting the letters DARPA on their sides (see Figure 8).[28]

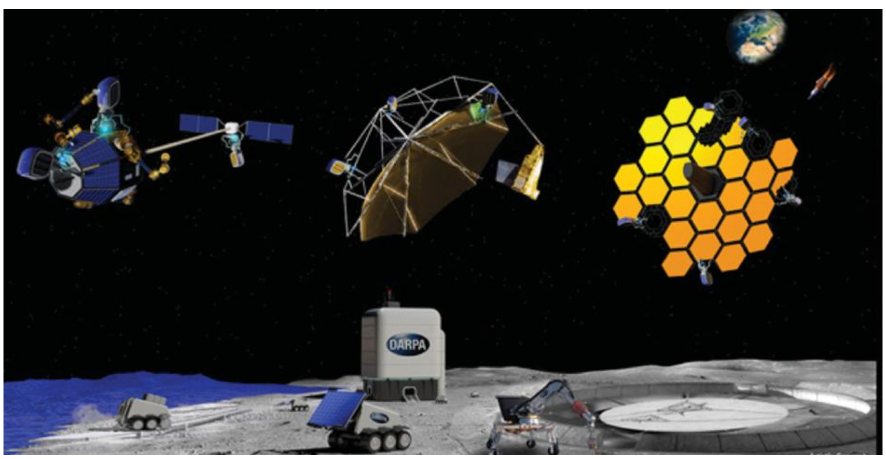

Figure 8. Artist's illustration of plans for a new DARPA program to develop designs and materials for building large structures in orbit and on the moon. Image courtesy of Darpa.mil according to the DARPA User Agreement (www.darpa.mil/policy/usage-policy).

[26] Mary Beth Griggs, "Earth's next mini-moon might be space junk from the 1960s," The Verge, 12 October 2020, at: https://www.theverge.com/2020/10/12/21512725/mini-moonspace-junk-nasa
[27] DARPA Public Affairs, "Orbital construction: DARPA pursues plan for robust manufacturing in space," 5 February 2021, Defense Advanced Research Projects Agency, at: www.darpa.mil/news-events/2021-02-05
[28] This image was later cropped to exclude the equipment and infrastructure on the surface. It is reasonable to infer that the change is due in part to domestic and international pressure, including this article written in response to the original image: Michael Byers and Aaron Boley, "Cis-lunar space and the security dilemma," (2022) 78:1 Bulletin of the Atomic Scientists 17–21, at: https://thebulletin.org/premium/2022-01/cis-lunar-space-and-the-security-dilemma/ . Importantly, cropping the figure is an implicit acknowledgment of the concerns raised.

Even if DARPA is not planning to actually engage in surface operations, it is easy to imagine other states reading the announcement as a statement of intent to militarize the Moon. The NOM4D program will consequently create uncertainty with regard to US plans and therefore feed the security dilemma. As Jessica West commented, “Blurring of civil, military, and commercial capabilities and intentions in space is exactly what the U.S. accuses other countries such as China of doing. It doesn’t build trust, and it doesn’t build confidence. And these two qualities are already in short supply. I don’t see how this ends well.”[29]

Then, in April 2021, DARPA awarded three contracts aimed at the development of a nuclear thermal propulsion (NTP) system for fast, highly maneuverable, long-duration spacecraft that would be deployed in cislunar space. The contracts, awarded to General Atomics, Blue Origin and Lockheed Martin, are part of the **Demonstration Rocket for Agile Cislunar Operations (DRACO)** program. According to program manager Major Nathan Greiner, it aims to “provide agile, responsive maneuverability (potentially across vast distances) within the cislunar domain for a variety of missions” and “conduct space domain awareness within the cislunar domain in a timely fashion.”[30] As the DARPA website explains:

> Rapid maneuver is a core tenet of modern Department of Defense (DoD) operations on land, at sea, and in the air . . . [The] NTP system has the potential to achieve high thrust-to-weight ratios similar to in-space chemical propulsion and approach the high propellent efficiency of electric systems. This combination would give a DRACO spacecraft greater agility to implement DoD’s core tenet of rapid maneuver in cislunar space.

In other words, it is hoped that nuclear thermal propulsion will provide both high power and high efficiency, and thus maneuverability and longevity. The plan is to launch the DRACO spacecraft in 2025.

There are at least two problems with the DRACO program. First, it would take the US military into cislunar space, which is fundamentally different from using military personnel as astronauts on civil missions. By extension, this would militarize that region and incentivize other militaries to follow. Second, “responsive maneuverability … for a variety of missions” suggests – and, more importantly, will be perceived as suggesting – an ability to engage in proximity operations around foreign spacecraft. These features of DRACO will likely feed a Chinese security dilemma.

3.4. LUNINT Dashboard

In October 2021, the US Air Force contracted a company called Rhea Space Activity (RSA) to develop a “lunar intelligence dashboard” to track and visualize objects in cislunar space, where spacecraft trajectories are complicated by “three-body” and “n-body dynamics.” RSA has partnered with Purdue University and Saber Astronautics on the project, which aims to deliver a Lunar Intelligence (LUNINT) Dashboard that will enhance the ability of the Air Force to monitor

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[29] Theresa Hitchens, “DARPA space manufacturing project sparks controversy,” Breaking Defense, 12 February 2021, at: https://breakingdefense.com/2021/02/darpa-space-manufacturing-project-sparks-controversy

[30] Theresa Hitchens, “DARPA nuke set to target cislunar monitoring mission,” Breaking Defense, 19 April 2021, at: https://breakingdefense.com/2021/04/darpa-nuke-sat-to-target-cislunar-monitoring-mission/

cislunar space.[31] So here again, we see the US developing capabilities for space domain awareness in cislunar space, without any apparent consideration as to whether this should be a military or civilian function.

4. CHINA

4.1. China's plans and progress in cislunar space

In March 2021, China signed a memorandum of understanding with Russia on the development of an "International Lunar Research Station". Seven other countries have since entered into similar agreements with China: United Arab Emirates, Pakistan, Venezuela, South Africa, Azerbaijan, Thailand and Turkey.

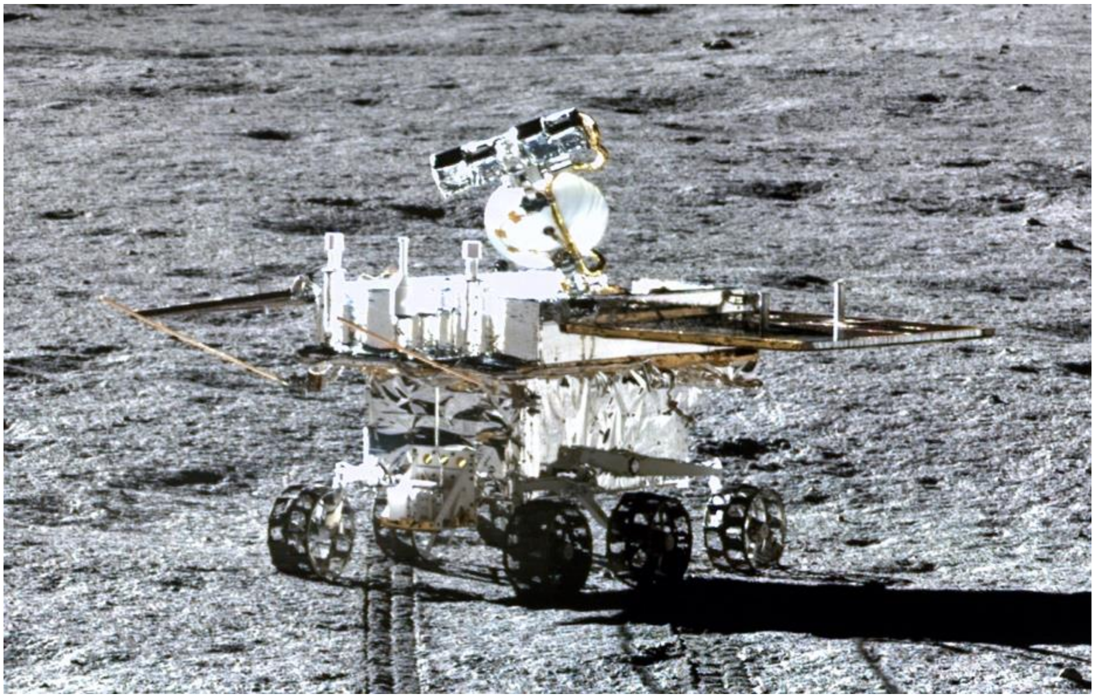

Figure 9. China's Yutu-2 rover has been operating on the far side of the Moon since 2019. Photo from Wikimedia Commons.

As it builds toward this goal, China has already made substantial recent progress with its robotic Chang'e program, including placing rovers on the lunar surface, conducting a lunar sample return mission, and operating spacecraft in Earth-Lunar Lagrange points for communication purposes.

[31] PR Newswire, "Rhea Space Activity Receives USAF Contract to Enhance Domain Awareness in Cislunar Space Rhea Space Activity Forges Ahead in Reducing Threats to U.S. and Allied Space Assets," 20 October 2021, https://www.prnewswire.com/news-releases/rhea-space-activity-receives-usaf-contract-to-enhance-domain-awareness-in-cislunar-space-301404780.html

4.2. US concerns

China's progress and plans have prompted concerns that it might develop superior capabilities in cislunar space, and perhaps even a dominant presence there.[32] Indeed, the US military's plans for cislunar space – including the AFRL and DARPA projects discussed above – are being justified as protection for NASA's Artemis Program.[33] The program aims to establish a space station – the Lunar Gateway – in a near-rectilinear halo orbit around the Moon, as well as a long-term human presence on the surface.

It is unclear what would motivate China to interfere with NASA's activities. The Moon's remoteness and extreme environment combine to make any activities extremely dangerous and expensive. Interfering with another state's activities in cislunar space would further increase the risks and costs to one's own projects and programs, and for what purpose?

Many decades could pass before extracting resources from the Moon's surface becomes economically viable. For the time being, mining will be for local building materials and operating a surface habitat, as well as extracting water for survival and fuel. Again, helium-3 and precious minerals do exist on the lunar surface, but their concentrations are so low that large-scale mining and processing would be required. All this means that China's lunar program could be aimed simply at pursuing scientific knowledge and stoking national pride – just as the Apollo program did in the 1960s.

Uncertainties about China's motivations create a need for engagement with Chinese-language documents as well as Chinese experts. Precautionary responses only make sense after a rigorous effort to eliminate or at least reduce uncertainties.

4.3. Legal precedents?

Despite the considerable practical challenges facing any lunar activities, one widely expressed concern is that China will establish a sustained presence on the Moon first and thus be positioned to engage in actions that will constitute legal precedents—developing new rules in its favour. Those who voice this concern urge the US to proactively do the same. For example, in August 2020, Steven Butow, the Space Portfolio-lead within the Defense Innovation Unit, said: "Much of our law that we follow today is established on precedents. And one of the things we don't want to do, is we don't want to let our peer competitors and adversaries go out and establish the precedent of how things are gonna [sic] be done in the solar system, beginning with the Moon."[34]

However, the only obvious effort to set precedents and create new rules in space is currently being led by the US. In 2020, NASA announced that it was seeking proposals from private companies to

[32] Liane Zivitski, "China wants to dominate space, and the US must take countermeasures," Defense News, 23 June 2020, at: www.defensenews.com/opinion/commentary/2020/06/23/china-wants-to-dominate-space-and-the-us-must-take-countermeasures

[33] Theresa Hitchens, "Space Force–NASA accord highlights cooperation beyond Earth orbit," Breaking Defense, 22 September 2020, at: https://breakingdefense.com/2020/09/space-force-nasa-accord-highlights-cooperation-beyond-earth-orbit

[34] Theresa Hitchens, "Industry says 'meh' to DoD cislunar space push," Breaking Defense, 28 August 2020, at: www.breakingdefense.com/2020/08/industry-says-meh-to-dod-cislunar-space-push

extract small amounts of regolith from the surface of the Moon and sell them to the agency. Any selected company would be required to collect between 50 and 500 grams and provide imagery of the material and data concerning its location. NASA would then buy the material, through an "in-place ownership transfer", without the company having to return the sample to Earth. NASA might then retrieve the material at some unspecified future time. Or it might not. Then-NASA Administrator Jim Bridenstine admitted that the planned purchases were aimed at creating more subsequent practice in favour of the US interpretation of the OST: "What we're trying to do is make sure that there is a norm of behavior that says that resources can be extracted and that we're doing it in a way that is in compliance with the Outer Space Treaty." One can also see the Artemis Accords, and US efforts to secure as many signatories as possible to what remains a non-legally binding instrument, as part of a strategy aimed at the development of customary international law.

Yet some people have gone further than Butow, warning that China plans to use its presence on the Moon to acquire control and exclude others. Charles Galbreath, a retired Space Force colonel, writes:

> The head of China's lunar program has referred to the Moon as the Diaoyu Islands, a direct reference to the first island chain in the Western Pacific. This invites comparison to the gray zone tactics demonstrated by China in pursuit of their self-interested goals and actions directed in isolation through their authoritarian regime, such as covert weaponization, territorial claims, coercion, and other aggressive behavior—conduct they have repeatedly and increasingly displayed in the Western Pacific. The United States and free spacefaring nations of the world must prevent China from enacting a similar strategy in the cislunar regime to protect future freedom of operations.[35]

Galbreath asserts that "Failure to act will yield the initiative to adversaries with competing interests, limit future options for peaceful engagement in space, and create an unsustainable precedent in the cislunar environment, ultimately ceding U.S. leadership in space and weakening our status globally."[36] His conclusion is expressed in almost apocalyptic terms: "The relative success in the race to the Moon could validate or invalidate the underlying political and socioeconomic systems of the US and China on a global scale, with freedom, transparency, and democracy on one side and authoritarian, state-controlled secrecy on the other."[37]

Yet the evidence upon which Galbreath bases his concerns is less solid than it appears. The quotation from the head of China's lunar program is cited to a book published by two members of the think tank community – Namrata Goswami and Peter A. Garretson, *Scramble for the Skies: The Great Power Competition to Control the Resources of Outer Space* (London: Lexington Books, 2020), p. 56 – that in turn sources the quotation to a 2018 news article from The Daily Beast, written by a freelancer in Hong Kong.[38]

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[35] Charles S. Galbreath, "Securing Cislunar Space and the First Island Off the Coast of Earth," Mitchell Institute Policy Paper, Vol. 45, January 2024, pp. 2-3, footnotes omitted, at: https://mitchellaerospacepower.org/securing-cislunar-space-and-the-first-island-off-the-coast-of-earth/

[36] Galbreath, "Securing Cislunar Space", p. 5

[37] Galbreath, "Securing Cislunar Space", p. 8

[38] Brendon Hong, "China's Looming Land Grab in Outer Space," The Daily Beast, 22 June 2018, at: https://www.thedailybeast.com/chinas-looming-land-grab-in-outer-space

The following assessment by Schingler, Samson, and Raju may be more accurate:

> China is also increasingly emphasizing the importance of lunar activity in its efforts to become a dominant space power, but is rather opaque about its goals and plans for the moon. As has often been discussed, Beijing does not make a clear distinction between military and civilian space activities, further obfuscating the matter. Experts have also noted that much of China's discussion of space in defense white papers is limited to vague challenges. This lack of clarity regarding objectives in cislunar space leaves room for further miscommunications and misconceptions by rival states. It may also mean that China has not yet made up its mind and could still be influenced by our actions.[39]

Our concern is that statements and actions by-and-from the US could precipitate a race to militarize cislunar space, rather than being a response to actual Chinese policies and plans.

5. EXISTING INTERNATIONAL LAW

Those who are concerned about China establishing precedents and new rules overlook an important fact: An extensive body of international law already applies in cislunar space, including the UN Charter, customary international law, the Outer Space Treaty (OST), and the Rescue Agreement.

The UN Charter has been ratified by 193 states, including all spacefaring states. Relevant provisions include Article 2(3) ("All Members shall settle their international disputes by peaceful means in such a manner that international peace and security, and justice, are not endangered.") and Article 2(4) ("All Members shall refrain in their international relations from the threat or use of force against the territorial integrity or political independence of any state, or in any other manner inconsistent with the Purposes of the United Nations."). Article 42, which gives the Security Council the power to "take such action by air, sea, or land forces as may be necessary to maintain or restore international peace and security", also extends to space.

Rules of customary international law that apply in space include those on state responsibility and treaty interpretation. The rules on state responsibility include "circumstances precluding wrongfulness", such as consent and necessity. These rules are relevant to space security because an action that might otherwise be illegal, and thereby provoke tension or even conflict, can be legal and non-irritating in the presence of consent or necessity. The rules on interpretation are important in space because the Vienna Convention on the Law of Treaties was concluded two years after the OST, meaning that rules codified in the Vienna Convention apply to the OST as pre-existing customary rules. These rules matter, for instance, in determining whether the Article II prohibition on "national appropriation" extends to commercial space mining.[40] If it does so extend, widespread agreement will be needed to legalize commercial mining—and provide specific rules for it. If it does not, specific rules will still be needed to ensure that mining proceeds in a safe and environmentally responsible way, thus helping to prevent tensions and conflict.

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[39] Schingler, Samson, and Raju, op cit.
[40] Article II reads: "Outer 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."

Then there is Article IV of the OST, which categorically prohibits all military activities on the Moon and other celestial bodies, with its second paragraph reading:

> The moon and other celestial bodies shall be used by all States Parties to the Treaty exclusively for peaceful purposes. The establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military manoeuvres on celestial bodies shall be forbidden. The use of military personnel for scientific research or for any other peaceful purposes shall not be prohibited. The use of any equipment or facility necessary for peaceful exploration of the moon and other celestial bodies shall also not be prohibited.

The paragraph is both specific and categorical about prohibiting military installations, the testing of any type of weapon, and military maneuvers. It is thus quite different from the more general references in Articles IX and XI of the OST to the "peaceful exploration and use of outer space".

The last two sentences of Article IV, second paragraph, do allow for *some* military involvement in lunar activities, provided it is limited to the use of personnel, such as US military personnel serving as NASA astronauts, as mentioned above. Moreover, the prohibition on military bases, installations and fortifications does not extend to equipment or facilities necessary for peaceful exploration. Collaboration between a military and a civilian space agency thus does not necessarily contravene Article IV, second paragraph, though a military carrying out an independent program on the Moon would likely do so. As Christopher Johnson explained in the context of the NOM4D program:

> If DARPA (or its contractors) are conducting activities on the Moon which are temporarily peaceful in nature (like refining in situ resources into fuel or other useful material), this is still a MILITARY activity, and therefore pretty clearly prohibited. It's not done under the banner of NASA, or part of an Artemis program with international partners, or any principally civil activity – it's just the US military conducting activities, with military aims and objectives in mind. On the surface of the Moon, this is strictly proscribed and prohibited.[41]

The NOM4D program certainly seems to be inconsistent with US legal commitments, thus providing another reason – in addition to the program's feeding a possible Chinese security dilemma – for the US government to change course. But in any circumstance, Article IV, second paragraph, will require interpretation according to rules of customary international law.

Other provisions of the OST of relevance in cislunar space include Article I, paragraph 2 ("Outer space, including the moon and other celestial bodies, shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies."), and Article VI (on responsibility for national activities, as discussed below in the section on non-state actors).

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[41] Theresa Hitchens, "DARPA space manufacturing project sparks controversy," Breaking Defense, 12 February 2021, at: https://breakingdefense.com/2021/02/darpa-space-manufacturing-project-sparks-controversy

In the future, Article IX of the OST will also become relevant in cislunar space. It reads in part:

> In the exploration and use of outer space, including the moon and other celestial bodies, States Parties to the Treaty shall be guided by the principle of co-operation and mutual assistance and shall conduct all their activities in outer space, including the moon and other celestial bodies, with due regard to the corresponding interests of all other States Parties to the Treaty. … If a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals in outer space, including the moon and other celestial bodies, would cause potentially harmful interference with activities of other States Parties in the peaceful exploration and use of outer space, including the moon and other celestial bodies, it shall undertake appropriate international consultations before proceeding with any such activity or experiment. A State Party to the Treaty which has reason to believe that an activity or experiment planned by another State Party in outer space, including the moon and other celestial bodies, would cause potentially harmful interference with activities in the peaceful exploration and use of outer space, including the moon and other celestial bodies, may request consultation concerning the activity or experiment.

The obligation to consult will become more relevant over time, as more states and private actors become involved in cislunar space and especially in dynamically restricted and desirable locations such as long-term stable lunar orbits and deep, ice-filled craters near the lunar South Pole. The question is, when does the obligation to consult become an obligation to coordinate or even to cooperate?

6. OTHER CHALLENGES

6.1. Space Situational Awareness (SSA) and Space Domain Awareness (SDA)

According to the 2022 US National Cislunar Science and Technology Strategy:

> Space situational awareness is the necessary foundation to enable transparency and safe operations for all entities operating in Cislunar space. As activities in Cislunar space increase, the U.S. government will define requirements for new space situational awareness capabilities, including associated reference systems and data-sharing approaches. …This objective has synergies with efforts to provide early warning for potentially hazardous asteroids ….[42]

As explained above, Earth-based telescopes and radar are inadequate for monitoring spacecraft in cislunar space. Nor can they monitor the far side of the Moon. Sensors to provide space situational awareness will be required in cislunar space itself. And there they will encounter the complications of the three-body problem. Galbreath gives one perspective on the consequences of this: "[T]he techniques used to track objects in the cislunar regime are closer to astronomy conducted by organizations like NASA than traditional domain awareness of objects following a predictable

[42] US National Cislunar Science and Technology Strategy, released November 2022, at: https://www.whitehouse.gov/wp-content/uploads/2022/11/11-2022-NSTC-National-Cislunar-ST-Strategy.pdf

orbit conducted by the military in the geocentric regime".[43] While Galbreath overstates the situation – astronomical observations are central to both Earth orbit SDA and cislunar SDA, with the NASA Orbital Debris Program Office and the European Space Agency Office of Space Safety playing fundamental roles already – he is right that cislunar SDA will require a different approach.

For all these reasons, one can make a strong case for sharing SSA data and establishing SDA cooperation in cislunar space. As Schingler, Samson, and Raju explained:

> As new systems to govern and monitor cislunar space are developed, there is a chance to reset how we approach topics of domain awareness and to acknowledge the need for openness and transparency. Sharing situational awareness data for the Moon could help to ensure that this increasingly complicated domain will continue to be used in a peaceful manner, allowing information to be freely shared with other operators from the outset. Funding could be pooled, sharing costs and diffusing tensions that might otherwise arise from individual military or national missions. Situational awareness will also be critical to establishing norms regarding notification and coordination as lunar activity increases.[44]

One can also make the case that both SSA and SDA in cislunar space should be the responsibility of civilian space agencies—with their existing expertise, both in astronomical observations, and in operating beyond Earth orbit.

6.2. Communications

Coordinating and sharing deep space communications systems can help to promote transparency and confidence building, thus helping to prevent a security dilemma. As it happens, there are already international data and system standards for deep space communications, established by the Consultative Committee for Space Data Systems (CCSDS) and followed by the deep space networks operated by the US, Russia, China, India, Japan and the European Space Agency. The CCSDS was created in 1982.[45] Presently composed of "11 member agencies, 32 observer agencies, and over 119 industrial associates", its standards have been used in more than 1000 space missions. There is also a history of cooperation between different networks, which enables better coverage and thus promotes safety and mission success. For example, NASA, which operates its own Deep Space Network, has an agreement with the European Space Agency that enables both agencies to use the other agency's network. Sharing of networks should be encouraged for all missions to cislunar space, including any military missions.

6.3. Positioning, navigation and timing (PNT)

The Global Positioning System (GPS) has been operational for three decades. It provides a remarkably accurate navigation and timing service from a constellation of 32 satellites in medium Earth orbit (MEO), at an altitude of about 20,000 km. The system is owned and operated by the US military but is very widely used by civilians—for navigation, banking, agriculture, search and

[43] Galbreath, "Securing Cislunar Space", p. 7
[44] Schingler, Samson, and Raju, op cit.
[45] Consultative Committee for Space Data Systems, at: https://public.ccsds.org/default.aspx

rescue, etc. GPS is no longer the only global navigation satellite system, with the European Union, Russia and China having their own systems: Galileo, GLONASS, and BeiDou, respectively.

As activities on-and-around the Moon increase, one or more PNT systems will be needed in cislunar space. But the costs of constructing such a system will be considerably greater than in MEO, making international cooperation highly desirable here. It also makes sense to ensure that the PNT system is controlled and operated by civilians, much like the International Space Station is today, so as not to feed security dilemmas. It might also make sense to combine PNT, SSA and SDA in the same spacecraft and, ideally, under a civilian international organization that includes the US and China.

6.4. Protection of radio spectrum: Radio astronomy

The Moon offers a pristine environment for studying radiofrequency emission from the universe, with the far side in particular being shielded from Earth-based emissions. Not surprisingly, the idea of placing radio observatories on the far side of the Moon has been around for quite some time and is now seeing concepts in development.[46] Breakthrough Listen (searching for extraterrestrial intelligence) is one example of many projects interested in using the Moon as a unique and unspoiled opportunity for conducting science.[47] Other examples include probing the early universe and studying the electromagnetic environments of planets around distant stars.[48]

Spacecraft in lunar orbits, orbiting about L points or stationed elsewhere in cislunar space could cause radio interference for these Moon-based observatories in bands that have already been lost to Earth-based facilities. Even a lunar surface-based communication network could cause substantial interference unless designed with the protection of radio astronomy in mind.[49]

Radio interference on the Moon is a foreseeable issue: The International Telecommunication Union identified the problem decades ago.[50] The 193 member-state organization is working to find solutions and mitigations, and is often able to adopt binding international rules—as amendments to its "Radio Regulations". But success will require that all lunar actors, including military actors, follow the rules and respect radio quiet zones. And this might require limiting the number of spacecraft as well as the portions of the spectrum and the directions of the beams they use. Having militaries racing to position spacecraft in cislunar space could complicate this necessarily co-operative exercise.

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[46] Saptarshi Bandyopadhyay, "Lunar crater radio telescope (LCRT) on the far-side of the Moon," NASA, 7 April 2020, at: www.nasa.gov/directorates/spacetech/niac/2020_Phase_I_Phase_II/lunar_crater_radio_telescope
[47] Eric Michaud, "Breakthrough listen: Lunar opportunities for SETI," (2020), University of California Berkeley, at: https://seti.berkeley.edu/lunarseti/
[48] A conference room paper to the Science and Technical Subcommittee of UN COPUOUS was recently submitted by the IAU Working Group for Astronomy on the Moon, at: https://www.unoosa.org/res/oosadoc/data/documents/2024/aac_105c_12024crp/aac_105c_12024crp_14_0_html/AC105_C1_2024_CRP14E.pdf
[49] Emma Alexander, "A 4G network on the Moon is bad news for radio astronomy," The Conversation, 23 October 2020, at: www.theconversation.com/a-4g-network-on-the-moon-is-bad-news-for-radio-astronomy-148652
[50] See: ITU-R RA.479-5, available at: https://www.itu.int/dms_pubrec/itu-r/rec/ra/R-REC-RA.479-5-200305-I!!PDF-E.pdf

6.5. Space traffic management

6.5.1. Collisions and debris

As explained above, the few lunar orbits that are long-term stable will attract human activity, which could lead to congestion, collisions and debris – creating operational hazards both in those orbits and on the lunar surface. Collisions or fragmentation events could also result from spacecraft being abandoned in cislunar space. Debris streams could even develop between lunar and Earth orbits. Challenges such as spacecraft disposal in the cislunar environment therefore need to be addressed in advance, with safe procedures being followed by all spacefaring states.

This situation calls for restraint and close international coordination, which competing militaries are rarely able to provide. On Earth, over the high seas, air traffic control is provided by national civilian agencies, coordinating under the umbrella of the International Civil Aviation Organization. In geosynchronous orbit, the International Telecommunication Union fulfills a comparable role by assigning slots to satellites. Something similar is already required in low Earth orbit—and will be required, one day, in cislunar space.

6.5.2. Lunar surface traffic management

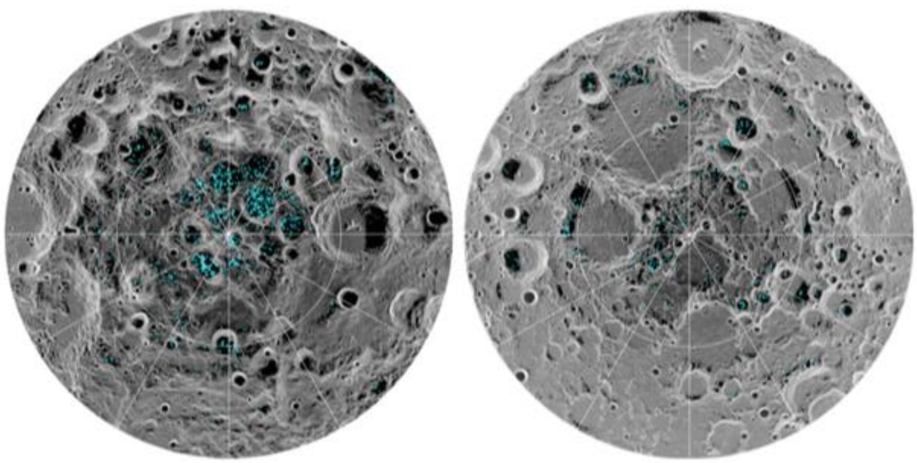

Figure 10: Map of the Moon's south (left) and north (right) poles, as taken by NASA's Moon Mineralogy Mapper instrument on India's Chandrayaan-1 spacecraft. The grey colour shows the temperature at the time of mapping, with cold regions shown in darker shades. The cyan points show where water ice was detected. Credit: NASA.

The Moon is very large but the areas of most interest to states and companies are relatively small. Attention is increasingly focused on water ice located in deep craters at-or-near the lunar South Pole. As states and companies explore those craters and eventually take measures to exploit the resource, protections for those activities – in the form of ongoing coordination, or perhaps some kind of safety zones – will be required. For if the activities of one actor cause interference with the activities of another, tensions and perhaps even conflict could result. Lunar surface traffic management is therefore an issue of cislunar security.

6.5.3. Coordination mechanisms and "safety zones"

A major issue of lunar surface traffic management involves ensuring that one actor does not impede another actor – or imperil its personnel, equipment or installations – by approaching too closely or causing dust lofting or radio interference of some kind. But what is a reasonable distance, and who gets to decide?

Galbreath writes:

> If China were to establish an infrastructure on the Moon, they could use it as justification to limit other nations' communications or other activities near it. For example, China could establish a "scientific" station in an area rich in lunar ice and require a keep-out zone to not interfere with their scientific research, thus effectively commandeering that region and the resources in it for their use while denying access to other nations.[51]

However, Galbreath fails to mention that the US government is actively proposing the creation of safety zones, with provisions in the Artemis Accords (Section 11 – Deconfliction of Space Activities) providing a starting point. While the Accords acknowledge that signatories commit to "respect the principle of free access to all areas of celestial bodies and all other provisions of the Outer Space Treaty in their use of safety zones",[52] additional language within the Accords focuses on using safety zones to avoid harmful interference and could be interpreted as forming the basis of the same concern noted by Galbreath. Will safety zones promote deconfliction, or will other states interpret safety zones in the way that Galbreath views potential Chinese actions? Inclusive multilateral negotiations are required – involving both the US and China as well as other states – to develop an approach that is acceptable to everyone.

6.5.4. Cultural heritage

Around the world, cultural heritage sites draw large numbers of tourists, which in turn requires that they be protected from harm. Any actions at or around cultural heritage sites on the Moon could put them at considerable risk, for instance, from lunar dust, and could therefore cause friction and even conflict between space actors. The protection of cultural heritage is thus an issue of space security. Inclusive multilateral negotiations are required to develop protections for cultural heritage sites, including the Apollo 11 landing site. In the meantime, national governments should ensure that all actors, including non-state actors, refrain from any activities that could cause harm.

[51] Galbreath, "Securing Cislunar Space", p. 12

[52] NASA, Artemis Accords, at: https://www.nasa.gov/wp-content/uploads/2022/11/Artemis-Accords-signed-13Oct2020.pdf

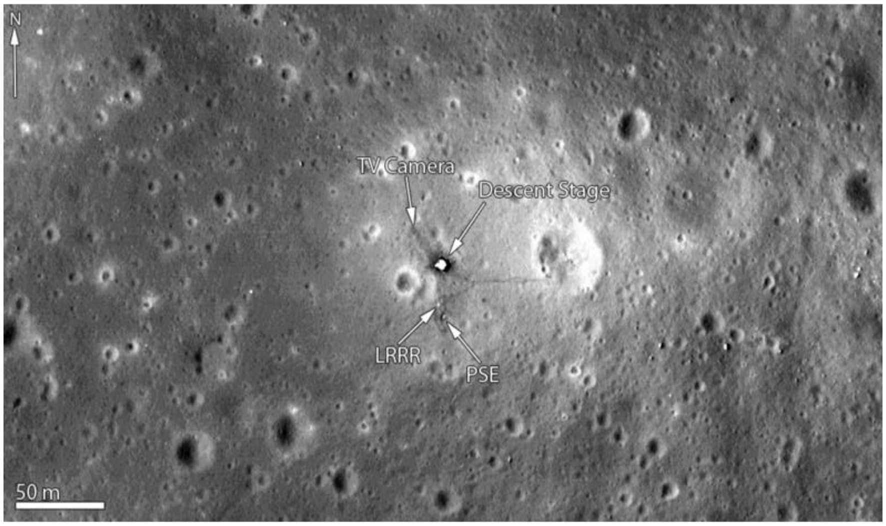

Figure 11. Apollo 11 landing site. NASA, at https://science.nasa.gov/resource/apollo-11-landing-site/

In addition to tangible cultural heritage, such as the Apollo 11 landing site, there is also intangible cultural heritage associated with the Moon. In 2023-2024, the Navajo Nation protested a private mission that aimed to deposit human remains on the lunar surface, with the Nation's president saying: "The moon holds a sacred place in Navajo cosmology. … The suggestion of transforming it into a resting place for human remains is deeply disturbing and unacceptable to our people and many other tribal nations."[53] Multilateral negotiations on cultural heritage, to be truly inclusive, will have to address intangible cultural heritage—and collaborate with Indigenous peoples.

6.5.5. Non-state actors

Non-state actors include companies, foundations, civil society groups, and terrorists.

While many commercial actors prioritize safety and sustainability, rules and regulations are needed to ensure that all actors are meeting or exceeding standard operational expectations. Indeed, companies sometimes behave negligently with disastrous consequences. Consider the 1984 gas leak at the Union Carbide pesticide plant in Bhopal, India, which killed more than 2000 people and injured half-a-million. Sometimes, they can behave criminally: A 2022 study funded by the Pew Charitable Trusts estimated that there are more than 100,000 deaths each year in the global fishing industry.[54] Many of these deaths are the result of violent acts that are never investigated.[55]

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[53] Kirstin Fisher, "Navajo Nation's objection to landing human remains on the moon prompts last-minute White House meeting", 6 January 2024, at: https://www.cnn.com/2024/01/05/world/peregrine-moon-mission-navajo-nation-objection-human-remains-scn/index.html

[54] Pew, "More Than 100,000 Fishing-Related Deaths Occur Each Year, Study Finds," 3 November 2022, at: https://www.pewtrusts.org/en/research-and-analysis/issue-briefs/2022/11/more-than-100000-fishing-related-deaths-occur-each-year-study-finds

[55] Ian Urbina, "How to get away with murder on the high seas," Al Jazeera, 6 December 2022, at: https://www.aljazeera.com/opinions/2022/12/6/how-to-get-away-with-murder-high-seas

Careless and illegal behaviour is more likely to occur when a company is acting outside of its state of incorporation, including in an area beyond national jurisdiction such as the high seas—or outer space. It is therefore essential that the non-state dimension be included in any discussion of cislunar security.

International space law does have one unique aspect that should make it easier to regulate private actions, namely, Article VI of the OST, the first two sentences of which read:

> States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty. The activities of non-governmental entities in outer space, including the moon and other celestial bodies, shall require authorization and continuing supervision by the appropriate State Party to the Treaty. …

As on Earth, the safety and security challenges created by companies and other non-state actors will require considerable prevention, mitigation and enforcement efforts on the part of national governments. But states that do not employ rigorous requirements for authorization and continuing supervision of private actors could become flag-of-convenience States and thus compromise the safe and sustainable exploration and use of cislunar space and the Moon

Given the unique challenges of cislunar space, one could imagine national authorities agreeing to cooperate on monitoring the activities of non-state actors, as well as on law enforcement, much in the same way as they do on Earth through extradition treaties, tax treaties, Interpol, and various forms of international judicial cooperation.

7. SEARCH AND RESCUE

Search and rescue should be considered a security issue, for several reasons. First, militaries are often the best equipped or positioned to conduct search and rescues. Second, search and rescue practices do not distinguish between military personnel or civilians needing rescue, nor does the duty to rescue disappear during armed conflict. To the contrary, it is part of international humanitarian law. Third, cooperation on search and rescue is sometimes one of the few remaining avenues for communication and confidence building between adversaries during times of international tension or conflict. Search and rescue networks and procedures can thus help to prevent escalation.

The duty to rescue is a central principle of international space law; so central, in fact, that the 1968 Rescue Agreement was concluded almost immediately after the 1967 OST to elaborate, via a dedicated treaty, on the duty to rescue as already set out in the OST. Although the drafters of the two treaties might not have foreseen that private citizens would fly on commercial spacecraft in the 2020s, they worded the duty to rescue in broad terms, and with the clear intent of having it apply to all human beings engaged in space travel. The same broad duty to rescue applies in customary international law, largely because of the near-universal acceptance of numerous treaty provisions on air, maritime, and outer space search and rescue.[56]

Rescues in cislunar space, including on the Moon's surface, will be difficult and expensive. But they will occur. At sea, states take the duty to rescue seriously, sometimes deploying aircraft and ships thousands of kilometers to save the crews of foreign ships and boats, whether publicly or privately owned. Although this practice is not always consistent – as sadly sometimes those same states look away when the human beings in distress are economic migrants or even refugees – international rules can exist without uniform practice or coercive enforcement.

The duty to rescue is not coupled with a right to be reimbursed for costs. Article 5(5) of the Rescue Agreement sets out an obligation, on the part of the launching authority, to bear the "expenses incurred in fulfilling obligations to recover and return a space object or its component parts". But the absence of a similar provision concerning the duty to rescue confirms that the rescuer bears the costs.

This raises the question whether there is a need for new international rules, or perhaps a compensation fund, to reduce the costs to states or companies when they engage in rescue missions. For instance, space companies could be required to carry insurance for the costs incurred by any rescuer. Alternatively, or additionally, space agencies and space companies could be required to maintain a rescue capability whenever they have human beings in space. Consider the best practice demonstrated by NASA, which held a Saturn V/Apollo and then a Space Shuttle on standby when astronauts were in space.

At a minimum, spacefaring states should consider creating an Outer Space Search and Rescue Forum, perhaps modelled on the Arctic Coast Guard Forum—formed in 2015 to respond to increasing demands on coast guard services in the maritime Arctic, including search and rescue.[57] Significantly, that forum involves all the Arctic states, including Russia, and was created one year after the Russian annexation of Crimea. It remains functional today, three years after the full-scale invasion of Ukraine. States were thus able to rise above a major source of geopolitical tension in one part of the world, to pursue cooperation in another domain.

8. CONCLUSION

As humanity expands into cislunar space, an approach based on transparency, coordination, cooperation, and collaboration offers the safest path forward for all states. That simple point is the essence of the "Moby's Recommendations on Lunar and Cislunar Security", which follow directly below.

[56] See: Michael Byers and Aaron Boley, *Who Owns Outer Space?* (Cambridge: Cambridge University Press, 2023), Chapter 1, at: https://www.cambridge.org/core/books/who-owns-outer-space/960CCB0464744F845B09434D932699EC
[57] Arctic Coast Guard Forum, at: https://www.arcticcoastguardforum.com/

Annex

MOBY’S RECOMMENDATIONS ON LUNAR AND CISLUNAR SECURITY

On March 1 and 2, 2024, the Outer Space Institute convened a group of experts (the Expert Group) from a variety of backgrounds, disciplines, and countries on Salt Spring Island, Canada, to discuss existing and foreseeable security-related challenges arising from activities on and around the Moon.

The following recommendations – named after one of the venues in which the Expert Group met – are the result of those discussions and are directed toward governments, inter-governmental and nongovernmental organizations, and other space actors.

These recommendations represent the individual views of the members of the Expert Group identified below. Their contributions to this document do not necessarily reflect the official policy or position of their institutional affiliation, whether a university, company, non-governmental organization, government (including departments, agencies and national militaries), or intergovernmental organization. Moreover, the Expert Group adopted the following recommendations as a consensus document; one that reflects the views of the group but not necessarily, in every respect, the views of each individual participant.

RECALLING the preamble of the 1967 Outer Space Treaty, in which 115 States Parties express that they are:

INSPIRED *by the great prospects opening up before [human]kind as a result of [humanity’s] entry into outer space,*

RECOGNIZING *the common interest of all [human]kind in the progress of the exploration and use of outer space for peaceful purposes,*

BELIEVING *that the exploration and use of outer space should be carried on for the benefit of all peoples irrespective of the degree of their economic or scientific development,*

DESIRING *to contribute to broad international co-operation in the scientific as well as legal aspects of the exploration and use of outer space for peaceful purposes,*

BELIEVING *that such co-operation will contribute to the development of mutual understanding and to the strengthening of friendly relations between States and peoples,*

RECALLING *resolution 1962 (XVIII), entitled "Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space", which was adopted unanimously by the United Nations General Assembly on 13 December 1963,*

***RECALLING** resolution 1884 (XVIII), calling upon States to refrain from placing in orbit around the earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction or from installing such weapons on celestial bodies, which was adopted unanimously by the United Nations General Assembly on 17 October 1963,*

***TAKING ACCOUNT** of United Nations General Assembly resolution 110 (II) of 3 November 1947, which condemned propaganda designed or likely to provoke or encourage any threat to the peace, breach of the peace or act of aggression, and considering that the aforementioned resolution is applicable to outer space,*

***CONVINCED** that a Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, will further the purposes and principles of the Charter of the United Nations,*

DEFINING "cislunar space" as the volume extending from Earth's geosynchronous orbits and encompassing the Moon, the Moon's orbits, the Earth–Moon Lagrange points, and certain types of transfer orbits,

RECOGNIZING that current geopolitical tensions pose challenges to global security including the safe and sustainable exploration and use of cislunar space,

EMPHASIZING that safety, security and sustainability are inexorably linked,

FURTHER EMPHASIZING that the orbital dynamics of objects in cislunar space are different from those in Earth orbits, and that this can lead to uncertainties and suspicions concerning actual and planned activities on and around the Moon,

COGNIZANT that many space actors have ambitions for activities on and around the Moon, including science, habitation, and resource exploitation,

ACKNOWLEDGING that many governmental and nongovernmental organizations have important roles to play in fostering the safe and sustainable use of cislunar space, including on the Moon,

RECOGNIZING that the activities of non-governmental entities require authorization and continuing supervision by the appropriate State,

ACKNOWLEDGING that some States are already planning to develop a long-term presence on the Moon while some States are not yet developing such plans,

SUPPORTING inclusive multilateral deliberations concerning the safe and sustainable use of cislunar space,

BELIEVING that the need to address the uncertainties associated with operating in cislunar space, as well as on and around the Moon, provide an opportunity for transparency, coordination, cooperation, and collaboration,

The Expert Group,

1. ***Calls* for inclusive engagement and decision-making concerning cislunar space, including the development of improved rules and best practices**
   - All States, irrespective of the degree of their economic or scientific development, must be involved in decisions regarding the exploration and use of cislunar space, including the Moon, without discrimination and on the basis of equality
   - All space actors must take into account that actions in cislunar space, including on the Moon, affect all peoples
   - All space actors must accept that scientific and legal experts, commercial actors, and civil society all have roles to play in the development of improved rules and best practices
   - In the development of improved rules and best practices, natural and cultural heritage, including intangible cultural heritage, must be valued

2. ***Calls* for greater implementation of the obligation of States to authorize and supervise commercial space actors on a continuing basis**
   - Commercial actors will play important roles in operations on and around the Moon
   - While many commercial actors prioritize safety and sustainability, rules and regulations are needed to ensure that all commercial actors are meeting or exceeding standard operational expectations
   - Article VI of the Outer Space Treaty stipulates that States "bear international responsibility for national activities in outer space, including the moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities," and that these activities "shall require authorization and continuing supervision" by the appropriate State
   - States that do not employ rigorous requirements for authorization and continuing supervision could become flag-of-convenience States and thus compromise the safe and sustainable exploration and use of cislunar space and the Moon

3. ***Encourages* the development of a shared knowledge base of relevant science and international and domestic law to promote informed decision-making on the exploration and use of cislunar space, including the Moon**
   - The lunar and cislunar environments place numerous physical constraints on operations in those regions, including orbital dynamics that are different from those in Earth orbits
   - There are many existing rules of international law that already apply on and around the Moon
   - However, there are many misconceptions concerning physical constraints and international law that can exacerbate suspicions between States and create complications for space operators

- The development of transdisciplinary expertise and inclusion of such expertise in policy, programmatic and technical decision-making will enable new opportunities regarding the exploration and use of cislunar space, including the Moon
- The development of a shared knowledge base should include public education efforts on the relevant science and law as well as the benefits and risks of the exploration and use of cislunar space, including the Moon

4. ***Encourages* the development and use of language and narratives that emphasize the benefits of transparency, coordination, cooperation and collaboration in the exploration and use of outer space, including cislunar space**
    - Much of the current rhetoric is alarmist and could fuel security dilemmas, whereby uncertainties and suspicions about the actions and motives of others could lead to the militarization and even the weaponization of cislunar space
    - Although the establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military manoeuvres on celestial bodies are already proscribed by Article IV of the Outer Space Treaty, security dilemmas could lead to situations whereby States push the limits of legitimate operations on the Moon and other celestial bodies
    - New language and narratives should be inclusive and gender neutral

5. ***Calls on* all States and other space actors to improve transparency, coordination, cooperation, and collaboration on and around the Moon**
    - Transparency, coordination, cooperation, and collaboration reduce risks to the safety and sustainability of one's own operations, including from conflict. They also prevent or reduce negative impacts on the environment, the protection of which is an interest shared by all States
    - Transparency, coordination, cooperation, and collaboration should include dedicated mechanisms, such as the sharing of situational awareness, other information, and positioning, navigation and timing (PNT) capabilities—to the greatest degree practicable
    - This can be done on a step-by-step basis whereby some transparency leads to additional transparency, as space actors learn to trust each other
    - This sharing should be done in a timely manner and in a usable format to promote operational sustainability and safety, avoid misunderstandings between States or other operators, and reduce decision-making uncertainties
    - A consultative process should take place for any projects having the potential to affect other space actors, or create uncertainties for them, and should involve a wide range of stakeholders

6. ***Urges* all States, working together, to develop rules, guidelines and best practices for debris prevention and mitigation in cislunar space**
    - Most orbital space about the Moon is unstable, and debris left in such orbits will impact the surface, creating risks for lunar operations.
    - The near-absence of an atmosphere rules out any reliance on ablation for reducing reentry safety risks on the Moon

- For lunar orbits that are stable, debris could accumulate in mission-critical orbits, compromising safety
- Debris ejected into cislunar space will become a challenge for Space Domain Awareness, and may impact the Moon or the Earth at a later time. Such debris, especially large debris pieces, also create interference for other forms of space exploration, such as astronomical observations
- Some space agencies are incorporating lunar environment considerations into their debris rules and guidelines, but more consistency in the content and application of such rules and guidelines is needed to address long-term safety risks, including to surface operations

7. ***Urges* all States to conduct a cooperative scientific operation on the far side of the Moon**
    - The participation of all States should be encouraged and supported
    - The cooperative operation should be consistent with existing treaty provisions
    - The cooperative operation may lead to a scientific facility, which should be open to scientists from all States
    - The cooperative operation should foster further collaborative missions and activities on and around the Moon, such as the coordinated development of open communications as well as positioning, navigation and timing (PNT) infrastructure
    - All operations must foster behaviour that respects lunar radio quiet regions
    - Operations on the far side offer unique science opportunities
    - Operations on the far side have a fundamental need for transparency, coordination, cooperation, and collaboration to avoid suspicions between States

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