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Lunar Policy Handbook

Moon Dialogs

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Moon Dialogs

———The Moon Dialogs is a partnership focused on governance and coordination mechanisms for the lunar surface. It is convened by organizations and participating researchers exploring voluntary, multilateral mechanisms, norms, and economic arrangements that aim to grow ecosystems of lunar activity. Our mission is to produce credible, actionable mechanisms facilitating lunar coordination, policies, norms and laws; leveraging voluntary frameworks and cross-sector, international support.

———The Moon Dialogs mission is to produce credible, actionable mechanisms facilitating lunar coordination, policies, norms and laws; leveraging voluntary frameworks and cross-sector, international support.

———We invite industry, government and academia on equal footing to join our discussions on these themes, with an emphasis on practical tools, operating models, and rights frameworks for the next 10 years. Moon Dialogs is not a consensus forum, but a place to put forward ideas which will accelerate short term activity and support bold plans for a sustained presence on the Moon.

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Foreword

by Tanja Masson-Zwaan, Board Member, Open Lunar Foundation

———This *Lunar Policy Handbook* is an important tool and topical resource for anyone interested in lunar exploration. The successful launch of the Artemis I mission illustrates humankind's determination to return to the Moon and making it a permanent destination for exploration as well as a stepping stone for further destinations such as Mars. Artemis and other lunar exploration projects will only be successful if they take place in a transparent and cooperative manner, and this requires a thorough understanding of policy implications.

———To facilitate future lunar missions in a cooperative and peaceful manner it is essential that law- and policymakers, government officials, diplomats, as well as engineers and scientists understand the policy and governance implications of lunar exploration. This handbook will assist them, whether they are recognized experts in the fields of space law and policy or less familiar with those fields, and whether they come from established spacefaring nations or from emerging and aspiring ones. In addition, students in policy, law and engineering as well as interested members of the public and civil society will also benefit from reading this book, written in an accessible manner and addressing a multitude of relevant aspects ranging from issues like site selection, benefit sharing or waste disposal to legal issues such as liability for damage, conflict resolution or the use of space resources.

———Another important group of readers who will benefit from this book are the pioneering entrepreneurs and aspiring starters in this new industry, for whom it is

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equally essential to understand the policy implications of the missions they are working on. After all, awareness of these aspects will improve their business case by enabling them to address certain issues from the start of the design phase rather than as an afterthought. This group may be particularly interested in the second part of this book, which follows a mission involving a lunar rover from launch till end of life, providing a realistic case scenario covering specific activities and their policy implications.

——— We are going back to the Moon, to stay, that much seems certain, but the challenge we must face is to do so in a peaceful and cooperative spirit, building further on the first six decades of space exploration, and taking into consideration the legitimate interests of all state and non-state stakeholders. The *Lunar Policy Handbook* is a timely tool to help us meet that challenge. Happy reading! ◆

Introduction

by the Moon Dialogs Convenors

——— At present, the international legal order regulating human activities in outer space treats activities in Low Earth Orbit (LEO), Geosynchronous orbit (GEO), deep space, on the Moon, and all other celestial bodies with almost identical rules.

——— The 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty) serves as the foundational text of international space law, and this binding international legal agreement, with 112 state parties, creates broad principles of governmental responsibilities and obligations which are balanced with expansive rights and freedoms of exploration and use of outer space. The Outer Space Treaty is supplemented with various other sources of international law developed at the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), including the 1968 Astronaut Rescue and Return Agreement, the 1972 Liability Convention, the 1975 Registration Convention, the 1979 Moon Agreement, along with various other sources of non-binding "soft law" pertaining to remote sensing, space nuclear power sources, and related issues.

——— The UN space law framework is further refined by various national domestic space legislation. And, via Article III of the Outer Space Treaty, the rest of international law, such as international environmental law, and international humanitarian law applies in principle, to outer space and to humankind's activity there.

———However, laws, rules, and regulations (or, more generally, norms) specifically applicable to lunar activity are lacking in specificity and clarity. How does the "due regard" obligation, found in Article IX of the Outer Space Treaty, apply to and between lunar actors? Or Article IX's obligation to avoid harmful contamination on the Moon? How does the Precautionary Principle - a foundational element of international environmental law - apply to lunar activities? Space law also requires that the Moon be used "exclusively for peaceful purposes" but do we know what that means? The plethora of unanswered (and currently unanswerable) questions is staggering.

———With the first commercial mission reaching the lunar surface, humanity has officially entered a new era of rule-making for the Moon. Unless we are careful, these rules might be developed haphazardly, in a way to serve first movers, and in a way that creates unwanted precedents. Unless we are thoughtful, these rules could lead to rivalries, monopolies, overexploitation, and tensions regarding the opportunities offered by the Moon, the Earth's nearest neighbour.

———The good news is that there is another way. The Moon Dialogs Conveners are convinced that the proactive and adaptive development of fair and effective norms and policies for lunar governance can and will enable a safe, sustainable, and prosperous future on the Moon for the benefit of all humanity. In furtherance of these beliefs, the *Lunar Policy Handbook* was created to help stakeholders navigate the nascent realm of lunar governance. Part One provides a snapshot of current

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legal and policy principles related to the exploration and use of the Moon, and is meant to provide foundational support to policy-makers interested in the governance of lunar activities. To complement this analysis, Part Two discusses the main policy questions raised by the various types of activities that will be conducted thereby. The main goal of Part Two is to help lunar operators (present and future) understand the policy implications and questions associated with their missions.

——— We hope that the *Lunar Policy Handbook* can enable focused multilateral and multistakeholder discussions on the development of policies and norms for the safe, peaceful, and sustainable conduct of lunar activities. We the Moon Dialogs Conveners know that these conversations will require time and effort and would be delighted to support them in partnership with all stakeholders, from policymakers to lunar operators, as relevant and appropriate. ◆

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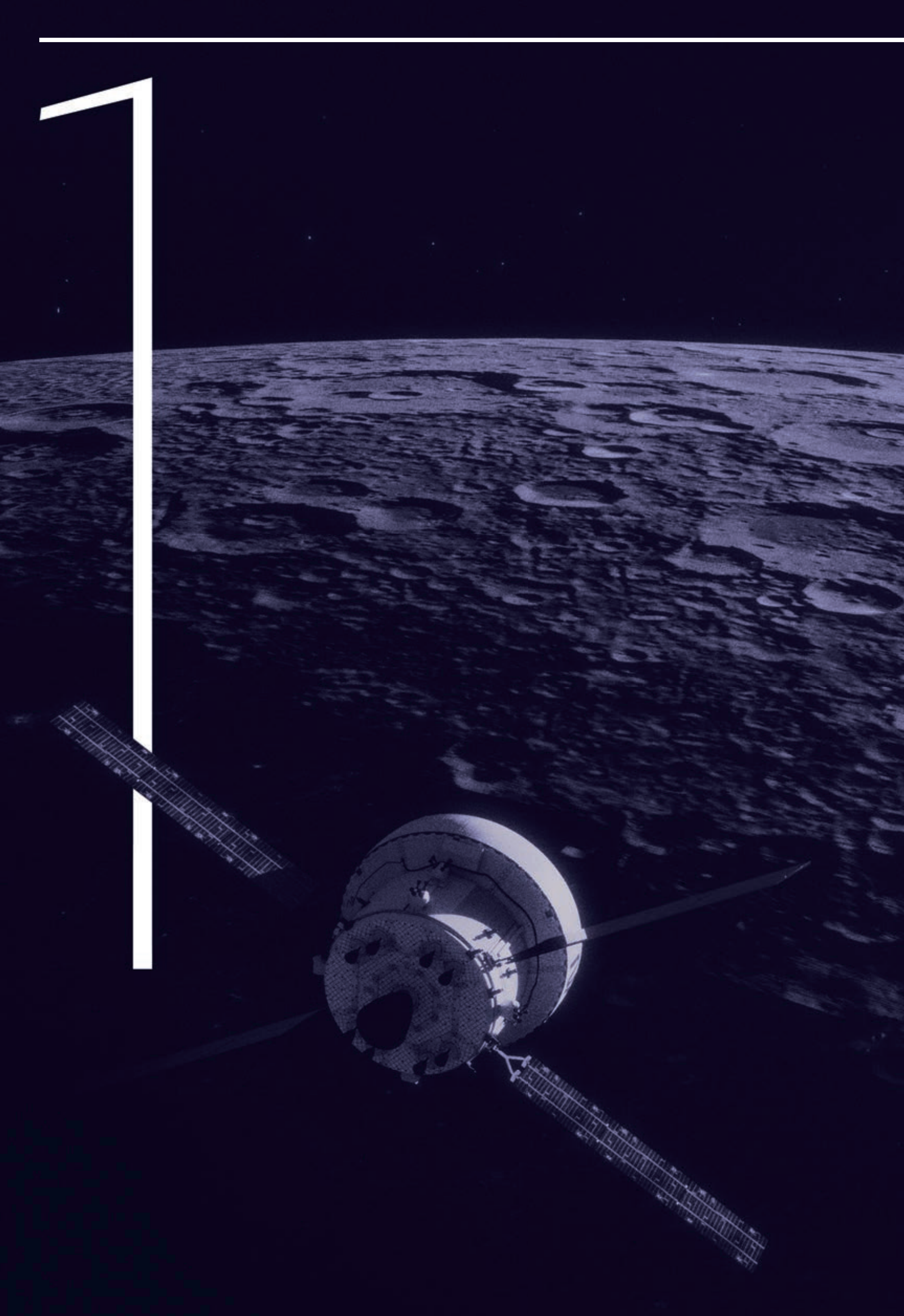

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Governance

Credit: NASA/Illustration by Liam Yanulis

01 Governmental Authorization and Supervision

by Christopher Johnson

The nation-state is the principal entity concerned with the authorization and supervision of lunar activities. This is because Article VI of the Outer Space Treaty designates states as internationally responsible (i.e., "answerable") for their national space activities. Article VI further places a positive obligation on states to authorize and to continually supervise their private commercial space activities, and to assure that these activities are in continuing compliance with both the treaty and (via Article III) the rest of public international law. These obligations of authorization and supervision, joined with international responsibility, serve as a strong encouragement for states to have explicit and uniform rules, such as national space legislation, to regulate their space activities. To date, many states already have national space legislation.

The obligations of responsibility, liability, and duties to authorize, supervise, and assure legal compliance also apply to lunar activities. However, no states have established laws specific to the authorization or supervision of non-governmental lunar activities.

Tasked with authorization and supervision, for assuring compliance with international law, and burdened with international responsibility and potential international liability, states looking at their own proposed national lunar activities must consider the context and consequences of any proposed activity. They should evaluate not just its lawfulness under international law but also its merit and attractiveness under other concerns and interests, including the political, economic, social, and cultural context and ramifications of that proposed activity. Significant efforts in clarifying the norms for lunar activities will be required in the years ahead. ◆

02 Licensing and Payload Determination

by Christopher Johnson

Historically, governmental licensing was executed in conjunction with space launch licensing and payload determination. However, as space activities continue to grow and diversify, multiple actors will be seeking governmental authorization. Currently launch providers, spacecraft operators, and various payload owners and operators are often different entities - sometimes combining governmental and non-governmental actors, as well as actors of different nationalities. However, national rules regarding licensing and payload determination lack the fidelity to evaluate activities at this level of specificity.

The governmental entity tasked with licensing and regulating it will need to consider what precedents are being set if they allow the proposed activity to proceed. This is a two-pronged question: (1) what are the consequences to the space domain and likely reactions by other actors, and (2) would they accept others also doing this activity, now or in the future? They may also consider whether their authorization might support or catalyze lunar activities, or might hinder these ambitions. Underpinning these considerations is the concept of sustainability. Sustainability means different things in different contexts, including "economically viable" for the commercial actor, "programmatically repeatable" for the mission manager, and "without deleterious long-term harm" for the environmentalist or conservationist. Each of these lenses is appropriate in considering lunar activity.

As these activities will be taking place on the lunar surface at almost 239,000 million miles / 384,633 kilometres from the nearest government office, the licensing authority will also need to consider the form and method of their supervision. In other words, once a commercial payload is headed to the Moon, it is likely not to return. Consequently, a full investigation and disclosure of its contents and capabilities while still on Earth is warranted. Similarly, activities conducted on the surface of the Moon have potential "rebound" implications for government liabilities and international relations back on Earth. Governments may want to consider means of increasing situational awareness, and using the tools of registration and reporting. ◆

03 Responsibility and Liability

by Harshita Khera

The principle of the international liability of states has two aspects: a general responsibility regarding national activities in space (Article VI of the Outer Space Treaty), and a liability regime regarding any damages caused by launched spacecraft (Article VII of the Outer Space Treaty). The use of the words responsibility and liability are not as similar as they seem since the first one does not necessarily engage any financial reparation, whereas the second seems to engage it.

In international space law, nation-states are internationally responsible for their national activities in outer space, including on the Moon. There is a unique attribution clause in Article VI of the Outer Space Treaty, whereby states assume responsibility for the actions of non-governmental entities. This concept was introduced to promote access for private actors in space while maintaining state supervision and monitoring. While Article VI aims to hold at least one state internationally answerable for an activity in space, in many cases more than one state can be responsible for a single activity, this is owed to the involvement of various actors like launch providers, spacecraft operators, manufacturers, launch procurers, etc.

In addition to international responsibility, there are provisions of international liability of states within space law as well. Article VII of the Outer Space Treaty stipulates that the state which launches, procures a launch, or from whose territory or facility an object is launched bears international liability for “damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts,” whether such damage is caused on Earth, in air, in outer space, or on the Moon and other celestial bodies.

The Liability Convention 1972 provides a comprehensive framework for assigning liability. Under the convention, damage refers to any loss of life, personal injury or other impairment of health; or loss of or damage to property, caused by a space object. A space object has been defined to include “component parts of a space object as well as its launch vehicle and parts thereof”, while launching also includes attempted launching.

The 1972 Liability Convention expands on the concept of absolute liability found in Article VII of the Outer Space Treaty, while also creating fault-based liability. An absolute liability standard, where liability is assigned regardless of fault, applies “for damages caused on the surface of the Earth or to aircraft in flight.” For damages suffered in space, a fault-based liability standard, as created in Article III of the Liability Convention, applies. A fault-based liability standard, therefore, applies to damages suffered on the lunar surface. However, specifics such as the standard of care that actors are under a duty to observe have, to date, not been specified.

Regarding compensation, the Convention requires that if a state is found liable, it is then under a duty to pay damages to restore the injured entity to the condition which would have existed if the damage had not occurred (i.e. restitution). However, in practice, states require companies to procure insurance as a condition for grant of licenses, while some states also have indemnification provisions. As a matter of practice, more and more companies are also including cross-waivers in their contracts with each other.

In both the responsibility as well as liability provisions, there are ambiguities which, although are being slowly reformed by state practice, still require clarification efforts on an international level. ◆

04 Site Selection and Occupancy

by Jessy Kate Schingler

In lunar activities, site selection and occupancy are important aspects of all landed missions. Article I of the Outer Space Treaty establishes the surface of celestial bodies as being subject to free access, and Article II prohibits national appropriation. With increasing mission activity and growing interest in commercial prospecting and service provision, site selection and occupancy will increasingly require the development of practical protocols that balance fledgling development, national interests, and integrity of the international legal regime.

The international community currently has no formal practices associated with site selection on the Moon. Historically, site selection has been an organic aspect of communicating a mission to the public, and in the near term, this is likely to continue. As knowledge about particular sites develops, there is also likely to be more concentrated interest in those sites. This increases opportunities for infrastructure and service provision, which are necessary and important for development; on the other hand, it may also increase the likelihood of contention.

The relationship between the principle of freedom of exploration and use of outer space and the principle of non-appropriation will also need to be clarified as different parties help to pursue the goal of sustained presence on the Moon. Basic questions such as how long one can occupy a site will need to be addressed, and what confidence one can have that a landing site selected for a future mission will not be occupied by another. Site occupancy also raises questions about disposal and non-interference, especially should there be a desire to reuse specific sites. Other questions such as where the liability falls when damage or interference occurs on occupied or previously occupied sites are raised.

The Hague Building Blocks proposed the concept of priority rights for site access, but implementing this will require the ability to evaluate the credibility and necessitate agreement on details such as transparency, benefit sharing, technical features, and intermediate usage; whereas, the Artemis Accords have proposed the concept of safety zones. Ultimately, their implementation will require international cooperation to clarify how these zones are established, their technical criteria and qualities, and differentiate between notification and exclusion, the latter of which is prohibited under Article I. ◆

05 Cislunar Space Situational Awareness

by Thomas G. Roberts

International space actors, (including civil, military, and commercial spacecraft operators) pursue two principal strategies when it comes to collecting the information they need to practice deconfliction with one another: active data sharing and passive data collection. In active data sharing, space actors privately or publicly distribute details that describe the behaviour of their spacecraft – such as historical orbital elements or position and velocity measurements—or plans for future manoeuvres that may alter their spacecrafts' trajectories. In passive data collection, space system operators gather this information independently by observing other actors' space objects from the ground- and space-based optical telescopes, radar systems, and other sensors and determining objects' trajectories algorithmically. Although data directly measured and shared by spacecraft operators are much higher fidelity than those collected passively—and more precise space object orbital data directly lead to lower uncertainties in deconfliction mission planning—there is no international treaty that requires space actors to engage in active orbital data sharing. Both active data sharing and the practice of sharing data derived from passive observation can improve transparency in space operations and form a foundation for developing norms of behaviour in the domain. Until data-sharing practices are improved, space operators will continue to rely on passive data collection for deconfliction amongst international actors, as they do for lower-altitude Earth-orbiting objects.

Space objects in the cislunar region, those with orbital trajectories that place them physically close to the Moon, are inherently more difficult to detect, track, and characterize than objects in more commonly used orbital regimes. Such objects pose unique challenges to space situational awareness (SSA), including detection, orbit determination, and space object catalogue maintenance. Compared to space objects that orbit the Earth in more familiar orbits, such as low Earth orbit (LEO), geosynchronous orbit (GEO), and medium Earth orbit (MEO), objects in lunar and cislunar orbits are generally much farther from the Earth's surface, exhibit long orbital periods, and appear near the Moon in the night sky, making them harder to observe from Earth. Each of these factors complicates SSA mission requirements in different ways.

Because space objects in cislunar space are often far away—many cislunar and lunar orbital regimes require observation at distances from the Earth's surface more than ten times greater than GEO altitude—they naturally appear dimmer and smaller to ground, LEO-, and GEO-based SSA sensors. Dimmer and smaller objects are more challenging to detect than brighter and larger ones for optical and radar sensors, respectively. Since many cislunar orbits have orbital periods on the scale of several days or weeks, they appear to move slowly in the sky and require more observations collected over longer observation periods for orbit determination when compared to lower-altitude, shorter-period objects. All objects in lunar orbits and many in cislunar orbits appear near the Moon during observation or even behind it. Because of light from the Sun reflected off the lunar surface, also known as the Moon's albedo effect, observing objects with small angular separations from the Moon can damage optical sensors and are routinely excluded from SSA sensor observation strategies. Failing to observe objects due to them passing within the Moon's exclusion zone—which includes objects near the Moon with a dark space background, objects that pass between the Moon and a sensor with a bright lunar background, and objects on the opposite side of the Moon from a sensor—results in a loss of custody and increases uncertainty in predicting future space object behaviour.

Currently, the United States' Space Surveillance Network (SSN), the Russian Military Space Surveillance Network, the European Space Agency's (ESA) Space Surveillance and Tracking Segment, and China's various networks of ground-and space-based assets do not include space-based SSA sensors at altitudes higher than GEO, according to public reports. However, as lunar and cislunar orbital regimes become more populated with space objects as a result of the advent of Moon-focused space operations in the coming years, SSA operators will likely benefit from placing sensors in more favourable orbits for cislunar object observability, such as those in orbit around Earth-Moon Lagrange points, high-altitude Earth orbits, and lunar orbits.

More exquisite passive SSA capabilities make up only a piece of the puzzle that is ensuring the peaceful and sustainable use of the cislunar space environment. In one high-profile example of the international SSA community's cislunar challenges—in which a rocket body was measured to be on a collision course with the Moon itself—better passive data collection may indeed have helped better predict when and where the collision would occur, but certainly could not have prevented the event from happening in the first place. Given its unique physical challenges, the cislunar space environment demands improved active data-sharing practices in addition to improved passive data collection. ◆

06 Lunar Coordination and Cooperation

by Dr. Antonino Salmeri

International space law attaches great importance to international cooperation and coordination. Primarily, these objectives are achieved through the obligations to pay due regard to the corresponding interests of others (Article IX of the Outer Space Treaty), consult in case of any potentially harmful interference (Article IX of the Outer Space Treaty), share fundamental information about space activities (Article XI of the Outer Space Treaty) and internationally register objects launched into outer space (Registration Convention).

In the lunar context, international cooperation and coordination will reduce the risk of conflict and support peaceful and sustainable lunar development.

As with many other ambiguous terms, the Outer Space Treaty does not define the meaning of "due regard". However, in international law, it is understood as a twofold obligation to (1) bear in mind the interests of other States and (2) refrain from activities that would unduly prejudice them. Based on this approach, to comply with the principle of due regard under Article IX of the Outer Space Treaty, States will have to make sure that the lunar activities for which they are responsible are not preventing others from undertaking parallel activities, either at the same or at a later point in time.

Another principle enabling lunar cooperation and coordination is information sharing. This principle is enshrined in Article XI of the Outer Space Treaty, according to which States agree to share fundamental information on their space activities with the UN Secretary-General, which in turn should be prepared to disseminate it immediately and effectively. If a State planning or authorizing lunar activities would share information on their nature, conduct, duration and location, this will enable other States to pay due regard to them. To achieve this purpose, it is important to share information through mechanisms and in a manner tailored to the needs of lunar coordination. The consultation mechanism under Article IX of the Outer Space Treaty could be used whenever an evaluation of the information shared reveals an appreciable risk of potentially harmful interference.

A significant threat to lunar cooperation may be posed by ongoing geopolitical tensions. For example, as a result of the sanctions adopted against the Russian Federation in connection with the war in Ukraine, ESA had to rearrange delivery to the lunar surface of its Exospheric Mass Spectrometer L-band (EMS-L), a science instrument that was originally scheduled to fly onboard the Luna-Globe lander in 2022 and will now be delivered to the Moon no earlier than 2025 as part of the joint JAXA-ISRO Lunar Polar Exploration Mission (LUPEX). Geopolitical tensions may also frustrate coordination by preventing bilateral

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consultations among certain states or blocking the adoption of collective measures and procedures in multilateral fora. For example, during the sixty-fifth session of the UN Committee on the Peaceful Uses of Outer Space, the Russian Federation opposed the inclusion of a sub-agenda item on lunar coordination that could have provided a useful opportunity for states to exchange information and consult about these aspects. ◆

07 Registration of Space Objects

by Dr. Antonino Salmeri

The registration of space objects is a longstanding principle of international space law enshrined in Article VIII of the Outer Space Treaty, and in Article II of the 1975 Registration Convention. Since the establishment of the UN Register of Objects Launched into Outer Space in 1962, the primary goal of international registration has been to serve as a key transparency and confidence-building measure. Within the context of lunar activities, this function will be especially important to ensure compliance with the obligation to use the Moon for exclusively peaceful purposes under Article IV (2) of the Outer Space Treaty. Registration will also solidify the exercise of quasi-territorial jurisdiction and control over the space objects in question, allowing states to fully comply with their obligations to supervise national space activities.

The current registration system has been designed to have orbital objects in mind and will need to be updated to fit the different needs of surface operations. For example, under Article IV of the Registration Convention, the mandatory information to be furnished when registering a space object refers to "basic orbital parameters", which would be inapplicable to objects on the surface of a celestial body. While this does not legally prevent the registration of lunar objects, it frustrates the practical relevance of registration because of the lack of useful information, for instance as in the case of the Apollo ascent stages which are simply reported to be "on [the] Moon". ◆

08 Natural Resource Management

by Héloïse Vertadier

Article II of the Outer Space Treaty outlines a basic principle that originally protected space and its resources from any international conflicts by forbidding any "national appropriation". The objective was to prevent an expansion of state sovereignty over a celestial body and to preserve the current balance between the space-faring powers and developing nations. However, despite the consistency of the wording of this principle, its scope remains vague and unclear. The new ambitions of the private sector have opened a discussion and a revisit of the interpretation of this principle by the states widening the field of possibilities for resource utilization.

The Moon Agreement also touches on the notion of resource utilization. However, the Moon Agreement failed to persuade any space superpowers, like the United States, Russia, China, the United Kingdom, Japan, or Canada and only has 18 ratifications. The reason for the lack of ratification can be found in Article XI. Contrary to Article II of the Outer Space Treaty, Article XI expresses that if property rights were to be created over the Moon and its resources, they would solely be held by the international regime on behalf of all states. It was envisaged that the international authority would afterwards establish leases or licenses to manage how lunar resources were to be used.

In the absence of an international consensus on space resource utilization, states started to publish national legislation authorizing such activities. Started in 2015 with the US Space Act, this momentum keeps growing as more states, such as Luxembourg, the United Arab Emirates and Japan, are joining this effort to clarify the rules surrounding space resource utilization. Further, states have been working on developing bilateral agreements regarding future lunar missions such as the CNSA and Roscosmos initiative with the International Lunar Research Station (ILRS), the NASA-led Artemis Program, and it subsequent Artemis Accords.

The Artemis Accords are bilateral agreements signed between NASA and space agencies and other countries that want to be part of the Artemis Program. The Accords codify principles highlighted by NASA as crucial to oversee the exploration of the Moon and the utilization of its resources. In particular, the Artemis Accords allow the extraction and the commercial use of space resources, thus reaffirming the principles of the 2015 Space Act. However, this approach to commercialization of space resources has been deemed US-centric by other space-faring nations, and the Artemis Accords have raised some concerns from a few space actors and are deemed to be a coordinated and planned attempt to refocus international space cooperation in favour of short-term US commercial objectives, with little consideration for the risks involved.

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Nevertheless, despite the concerns raised by the authorization of the commercialization of space resources triggered by the US, it seems that this interpretation of the principles of the Outer Space Treaty is becoming more and more accepted by space actors and many private companies as well as state actors who are planning on using lunar resources in the near future. ◆

09 Benefit Sharing

by Nivedita Raju

As lunar activities grow and diversify in scope and ambition, it is imperative to understand the significance of 'benefit-sharing' under international space law. Article I of the Outer Space Treaty provides states with the freedom to explore and use outer space. However, this freedom is not absolute. Article I specifies that exploration and use of outer space, including the Moon, "shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development" and that the exploration of outer space is the "province of all mankind."

In particular, the right to explore outer space should be exercised "without discrimination of any kind, on a basis of equality, and in accordance with international law." The subsequent provisions of the Outer Space Treaty, in addition to the other four space treaties, provide conditions and obligations that limit this freedom and instruct how the exploration and the use of space, including the Moon and other celestial bodies, should be carried out.

Article I thus imposes a binding obligation on all states to actively practice non-discrimination and forms the basis of the "benefit-sharing" obligation in international space law. As evidenced in the negotiation history of the Outer Space Treaty, this provision was included in the operative part of the Treaty through the proposal of Brazil. This indicates the drafters' intent to ensure a level playing field for states to benefit from space.

Implementing this principle and ensuring practical compliance with the benefit-sharing obligation has, however, proved challenging. Space technologies are not uniformly available to all states, and capital and scope for investments are limited (or absent) among developing states. Certain space activities are more readily achievable by some states and private entities than others.

Since some lunar resources are finite, this potential scarcity seems to indicate that unfair advantages would fall to those who can undertake lunar activities first. There has grown a renewed emphasis on the need for space policies that do not favour "first-movers." Yet translating the equitable distribution of benefits through Article I is challenging because this relies on cooperation between states, which cannot be forced. In an attempt to advance cooperation and benefit-sharing in the interests of developing states, the UN General Assembly adopted the Benefits Declaration in 1996. The Declaration does not create new obligations, and more generally proposes avenues for international cooperation. Continuous references to the benefit-sharing obligation have been made in subsequent UN General Assembly Resolutions and reports, which encourage states to cooperate on this basis.

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Future policies must therefore be developed in a manner that both encourages the conduct of lunar activities, but upon the condition that there are suitable mechanisms to protect the interests of non-spacefaring states. The priorities of developing states, even with regard to lunar activities, can also differ widely and there is an urgent need to engage in capacity-building at the multilateral level to fully understand these perspectives. The exchange of views and interests may steer states towards further cooperation, and help ensure that the legal obligations in Article I are effectively realized. ◆

10 Taxes

by James Anderson and Alex Rigby

The Outer Space Treaty and other international agreements of a similar era focused on the activities of nation-states. Since taxation is domestically regulated by individual states, there is an absence of a clear, internationally-consistent framework for the taxation of private enterprises in relation to their actions in space. As private actors continue to plan and execute profit-motivated missions from Earth, adjusting current terrestrial regimes of taxation is an increasingly important priority for those actors, launch states and the wider international community.

Fundamental questions remain as to what the aims should be of this system and how it should be implemented. Also, tax can be used to incentivise as well as penalize or discourage. So, should tax rules adjust to incentivise investment and development? Should regimes incentivise private actors to assist with the enforcement of international agreements historically aimed at state actors (e.g., through tax credits for the clean-up of debris as part of missions), or should there be instead a gross revenues tax to pay for such clean-up? Should the system be designed, e.g. through internationally agreed excise or royalty taxes the proceeds of which can be shared, to support responsible and equitable use of scarce resources (e.g., lunar resources and geostationary orbit slots)? How can tax help minimize externalities that impact the use of the "province of mankind" by others and thereby avoid a so-called "tragedy of the commons"?

To date, disputes in the taxation of outer space activities have largely arisen in respect of satellite activities. In those cases, three (or even four) states might seek to exert taxing rights over profits from the transmissions, namely: (1) the launch state; (2) the state in which the operating enterprise is located); (3) the state over which the satellite is orbiting, particularly if it is in geostationary orbit; and (4) the state in which services are being provided. States are starting to impose indirect tax obligations in respect of services supplied into their jurisdiction from space, and the international debates over how to appropriately tax the digital economy have also influenced states in imposing a direct tax on satellite services based on definitions of nexus that move beyond traditional concepts of permanent establishment.

It is clear to see that similar disagreements on which states have taxing rights could arise in respect of the use of lunar resources. For example, the scarcity of resources such as water ice at the lunar poles may lead to disputes between states that subscribe to the principles of the Moon Agreement, and those that believe the exploitation of resources by private actors does not violate the prohibition of national appropriation in the Outer Space Treaty. Without consensus being sought at the governmental level, however preliminary, those

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disagreements could incentivise states to utilize their taxation systems to support their interpretation and space-faring ambitions. Additional complications may also arise if an enterprise or individual claims to be resident outside of any terrestrial jurisdiction for profits taxation or asset jurisdiction, such as over intellectual property. Lessons were learned regarding the resources of the high seas, and Antarctica before it was too late. The same approach should be adopted regarding taxation in the lunar context. ◆

11 Heritage, the Lunar Environment, and Planetary Protection

by Michelle Hanlon

As lunar activities are increasing, questions regarding the environmental impact of these activities, including, heritage protection, disposal of spacecraft, dust contamination and scientific preservation of certain lunar sites are becoming pressing matters to consider.

Some environmental protection mechanisms already exist. Article IX of the Outer Space Treaty obliges states to "pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them to avoid their harmful contamination." The need to consider the effects of what is known as "forward contamination" is essentially an expression of the obligation of humans to explore space responsibly and sustainably.

The Committee on Space Research (COSPAR) is generally recognized as the authoritative body guiding compliance with Article IX of the Outer Space Treaty. The Committee promulgates guidelines "to be considered in the design of space missions, to protect investigated solar system bodies from biological contamination." When COSPAR developed its first code of conduct in 1964, the primary goal was to "protect planets with the potential for life precursors, paleobiotics, and possible extant life from being contaminated by Earth indigent biota, and which might result in compromising or destroying scientific efforts to whether life existed or exists on other planets in the solar system."

The COSPAR Planetary Protection Policy implements five categories for target body/mission type combinations and their respective suggested ranges of requirements. The Moon is Category II where there is "significant interest relative to the process of chemical evolution and the origin of life, but where there is only a remote chance that contamination carried by a spacecraft could compromise future investigations." Thus, there exist no established protective measures – simply a requirement that simple documentation (to include intended impact target, impact strategies, and end-of-mission reports providing the location of impact if it occurs) be prepared and, presumably, shared. There are no legal obligations to do such preparation and sharing. In short, there are few restraints on any lunar activities and no protections for any sites, natural or historic.

While no state has incorporated COSPAR Policy into their national laws, it is recognized that meeting the requirements addresses the burden and responsibility on states imposed by Article IX of the Outer Space Treaty. And indeed, many space-faring actors, including the United States, the European Union, and Japan, have implemented their internal policies. The US policy includes the protection of certain sites of particular scientific or historic interest, but this unilateral measure is not binding on other states.

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The COSPAR model encourages flexibility based on understanding and learning. Nations are urged to adopt or adapt the COSPAR Policy for Planetary Protection as part of their licensing process, in keeping with their responsibilities and obligations under Article VI and Article IX of the Outer Space Treaty. Similarly, the international community must address the other aspects of planetary protection which have heretofore been ignored, namely the recognition and protection of sites of natural, scientific, or historic importance, and defining a common international process to obtain such protection. ◆

12 Peaceful Purposes

by Cara Bieber

LPH—P/1

Article III of the Outer Space Treaty establishes that all activities taking place on celestial bodies must be conducted for peaceful purposes in accordance with international law, and the UN charter, "in the interest of maintaining international peace and security and promoting international cooperation and understanding." It has to be noted that the definition of peaceful purposes has been debated since the Outer Space Treaty came into force and its meaning has evolved with the increase in space activities.

The preamble of the Outer Space Treaty officially recognizes the exploration and use of space to be for peaceful purposes. The Outer Space Treaty further establishes that there will be no military installations on celestial bodies and explicitly bans stationing weapons of mass destruction in outer space. Though neither peaceful purpose nor weapons are defined, Article IV forbids the establishment of military bases, installation, fortifications, the testing of any type of weapons and the conduct of military manoeuvres on celestial bodies. Article IV further clarifies that exceptions apply to the use of military personnel for scientific research or for any other peaceful purposes.

The term 'peaceful purpose' remains ambiguous, and continues to evolve. Currently, the term 'peaceful purposes' is meant to encompass non-aggressive activities. However, the U.S. December 2020 Space Policy states "consistent with [the peaceful purposes] principle, the United States will continue to use space for national security activities, including for the exercise of the inherent right of self-defence." Here, the term peaceful purposes is being used to include activities constituting self-defence.

The peaceful purposes principle is likely to be at the heart of numerous debates in the upcoming years. There is still a need at the international level to clarify and define peaceful purposes as lunar activities increase. ◆

13 Conflict Resolution

by Christopher Johnson

It is entirely likely that lunar activities will result in competition and rivalries. Some of this competition might develop into noble competition, where the achievements and drives of one actor spark ambitions, dedication, and renewed drive in other actors in a virtuous circle of increasing accomplishment and sophistication. However, competition may also escalate into a vicious competition, rife with prejudice, tensions, misperceptions, mistrust, and outright hostilities. In light of that possibility, the Outer Space Treaty mentions in numerous places that space exploration should be for peaceful purposes, and in accordance with international law, including specifically the UN Charter.

Article IX of the Outer Space Treaty creates obligations of cooperation, mutual assistance, due regard, a prohibition on harmful contamination of space and celestial bodies, and a positive obligation to consult if harmful contamination is threatened. Furthermore, Article IX also creates a state's right to request consultations with another state which threatens harmful contamination of space or celestial bodies; and the corresponding obligation of the receiving state to engage in such consultations with the state requesting consultations. In sum, various provisions of the Outer Space Treaty stand ready to avoid or defuse conflict, including conflict involving lunar activities.

Article III of the Outer Space Treaty incorporates the rest of international law as applicable to activities in outer space. Consequently, the avenues for the peaceful settlement of disputes via the International Court of Justice (the ICJ, the principal judicial organ of the United Nations) as well as the Permanent Court of Arbitration (PCA), both situated at the Peace Palace in the Hague, Netherlands, also exist for disputes involving lunar activities.

The Articles on Responsibility of States for Internationally Wrongful Acts (ARSIWA), developed by the International Law Commission (the UN General Assembly's Sixth Committee) were adopted in UNGA Res. 56/83 in 2001 and codify consequences for internationally wrongful acts. An internationally wrongful act is an act or omission that is both attributable to the state under international law and constitutes a breach of an international obligation of the state. The consequences of an internationally wrongful act include the violating state's legal obligations of cessation and non-repetition of and reparations for the wrongful act.

In 2011, the Permanent Court of Arbitration (PCA) promulgated its Optional Rules for Arbitration of Disputes Relating to Outer Space Activities. The PCA Optional Rules are based on 2010 UNCITRAL Arbitral Rules and are procedural in nature – with rules on the composition of an arbitral tribunal, provisions

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regulating proceedings such as the proceedings location, language of the proceedings, claims, evidence, hearings, experts, etc., and rules relating to the Decision and Award of the Arbitral Tribunal. To date, no state has yet availed itself of the PCA's optional rules for space-related disputes.

There have not been any successful liability claims for space activities, on the Moon or otherwise, yet. This inactivity through official channels, either the PCA's optional rule or through the provisions of the Outer Space Treaty, does not mean that states have not objected to the behaviour of other states in outer space. Indeed, the intentional destruction of space objects through antisatellite (ASAT) demonstrations has occasioned polite yet persistent remonstrance at the UN level.

Currently, there are no instances where the consultation provisions of Article IX have been triggered. However, recently, owing to the launch of mega-constellations, a state sent a note to the UN Secretary-General pursuant to its obligations under Article V of the Outer Space Treaty, describing a "phenomena they discover in outer space… which could constitute a danger to the life or health of astronauts." Such a procedure, while still shy of triggering the consultation provisions of Article IX, or of accusing another state of an internationally wrongful act, seems to be a mannered diplomatic step towards conflict resolution. ◆

14 Disposal, Debris, and Salvage

by Christopher Johnson

The disposal and salvage of materials from lunar operations is yet another area for governments to consider. However, there is no guidance in existing international space law regarding the disposal, re-use or salvage of space objects in orbits, or on the lunar surface. Norms, policies, and international coordination will be needed to promote responsible lunar disposal and salvaging.

Article VIII of the Outer Space Treaty codifies a state's right to assert its jurisdictional powers over its launched space objects (and their component parts and personnel) which that state has placed on its national registry of space objects. Jurisdiction, the power of a state to pass laws, enforce those laws, and settle disputes arising under those laws, is a fundamental component of a state's sovereignty. Due to the limitation on territorial sovereignty over space or celestial bodies presented in Article II of the Outer Space Treaty, the jurisdictional power provided for in Article VIII is what remains of a state's sovereignty once extended in outer space – a zone beyond state territory, and shared amongst nations.

Article VIII also addresses ownership, stipulating that the "ownership of objects launched into outer space, including objects landed or constructed on a celestial body, and their component parts, is not affected by their presence in outer space or on a celestial body or by their return to Earth." Consequently, all human-made space objects are retained by their owners and are under the legal authority of their launching state. As such, at present, there is no clear method to legally dispose of space objects in a way that extinguishes these jurisdictional links.

While a space object can be removed or delisted from a national registry, the launching state of that object will always be considered its launching state, and therefore potentially liable for resulting damage. Even a piece of non-functioning debris from a completed mission falls into this framework of persistent potential liability. It is also arguably still the "national activity" of some authorizing state, with attendant international responsibility attached.

The corollary to this difficulty is that there are no clear legal methods or avenues for the re-use or salvage of space objects by other actors. An abandoned space object subsequently found is still, in principle, under the jurisdiction of some state, still a launched space object with attendant potential liability, and still arguably part of some nation's national space activity with attendant international responsibility. Consequently, significant policy and legal innovation will have to be accomplished to clear the way for actors in space and on the Moon to permissibly re-use, salvage, seize, and legally own human-made objects, including debris, which they make or find in space or on the Moon. ◆

Conclusion to Part One

———The previous sections have attempted to explain specific elements of a national government's authorization and supervision of its national space activities in and around the Moon, including the activities of its private, commercial lunar actors. The elements of international law, whether specific provisions of international space law or general principles found across international law, apply to space activities in general, including lunar activities. However, these provisions are general and can be said to lack specificity for a wide variety of activities on the Moon. This half of the *Lunar Policy Handbook* explains these obligations and duties, as well as freedoms and rights, on the Moon, and can also be thought of in the context of Part Two, the second half of the *Lunar Policy Handbook*, which looks at actual lunar activities as they are planned and anticipated. ◆

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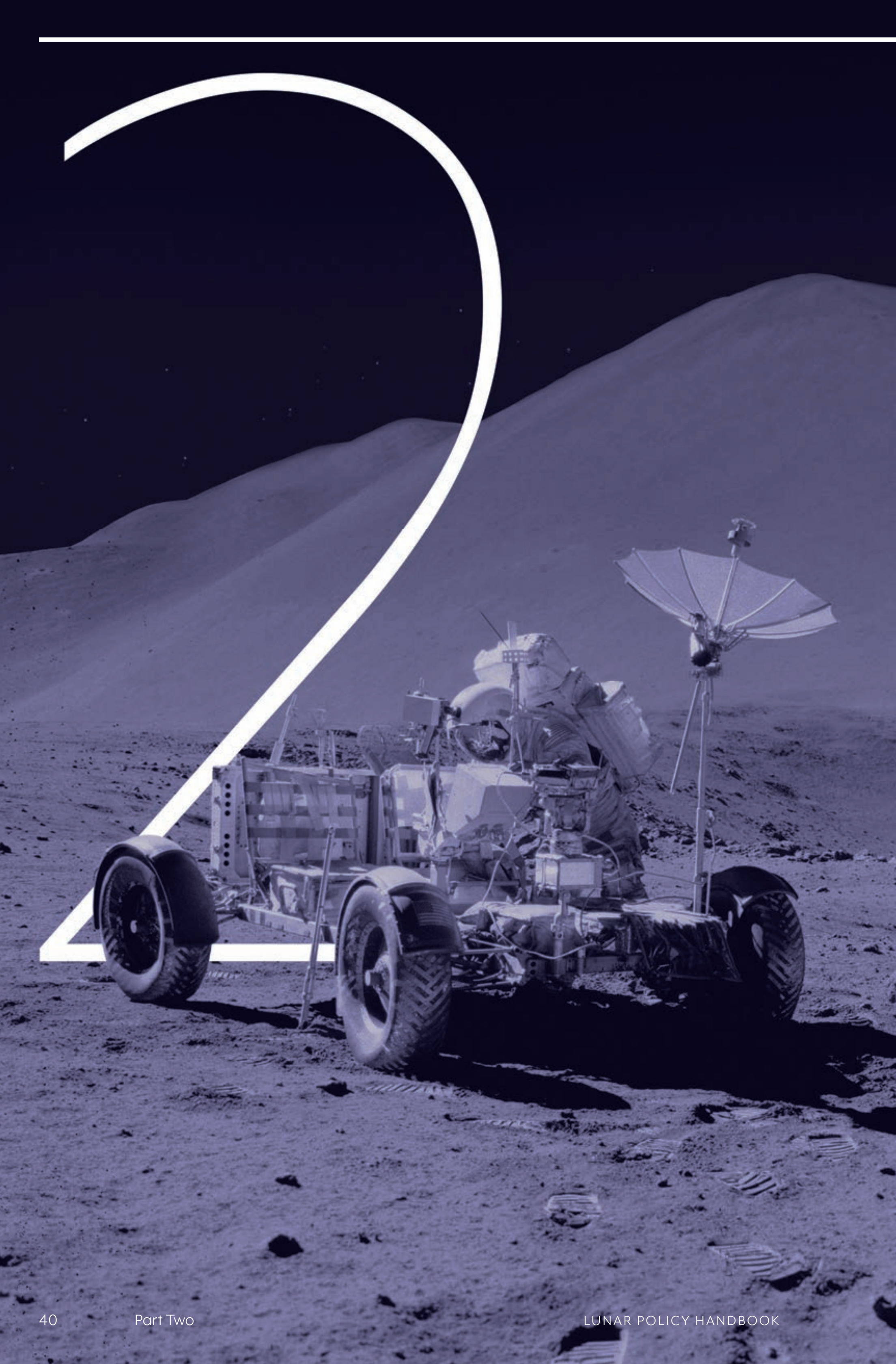

LPH—P/2

Implementation

Credit: NASA

Introduction to Part Two

by Harshita Khera and Héloïse Vertadier

———This decade is an exciting time for lunar activities, over the next few years there are multiple missions headed to the Moon, both scientific and commercial. This presents an opportunity to set valuable precedents focusing on a cooperative and sustainable presence.

———While Part One of the *Lunar Policy Handbook* focuses on lunar policy and governance framework within existing international space law and the need for clarity, Part Two offers a zoom-in approach based on the activities that are likely to take place on the surface of the Moon. This part is divided into 8 chapters, with each chapter describing a specific type of lunar activity and its subsequent policy implications. The chapters are organized as a mission leaving Earth, landing on the lunar surface, and following through to the end-of-life activities.

———The missions overview table provides a snapshot of lunar missions planned for the next three years. This table is added for referral within Part Two as it lists relevant payloads and the descriptions of each mission.

———To understand the different policy implications of each type of activity, the chapters have been written following a unified format. After introducing the type of activity which will be the main focus of the chapter, the key stakeholders' group of the activity will be presented, followed by a description of the relevant missions, the opportunities and need for coordination, the policy precedents that these missions might set, their lacunae and associated risks, the potential conflicts that can arise from those, and finally the author's recommendations and actions that could be taken as countermeasures.

———The chapters are independent and they do not need to be read in order. They were written as a source of information for actors who want to either learn more about the policy implications of certain activities, or actors who are developing their lunar missions and wonder what policies would be interesting for them to be aware of. In that context, Part One serves as a reference guide to learn more about the policy questions raised in Part Two. ◆

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01 Missions Overview

by Héloïse Vertadier and Dr. Antonino Salmeri

PLANNED DATE	MISSION	ORGANIZATION	LANDER
Nov. 2022	HAKUTO-R Mission 1 (M1)	ispace	HAKUTO-R Lander
Nov. 2022	Artemis 1	JAXA	Omotenashi Lander
Early 2023	Peregrine Mission 1	Astrobotic	Peregrine Lander

This section provides a summary of the lunar activities currently being planned until the end of 2025. To facilitate reading, these missions are organized into a table.

PAYLOADS	MISSION DESCRIPTION
• The Rashid Lunar Rover • A Transformable Lunar Rover • A trial design of solid-state battery technology • An AI flight computer • A set of multiple 360° cameras	HAKUTO-R is a lunar lander developed by the Japanese company ispace, scheduled to launch to the Moon under the HAKUTO-R Mission 1 on a SpaceX Falcon 9 Rocket from Cape Canaveral and land near the Lacus Somniorum between November 9-15, 2022. If successful, the HAKUTO-R Mission 1 will turn ispace into the first commercial company to ever achieve a soft landing on the Moon, delivering governmental and commercial payloads.
• A radiation monitor • An accelerometer	OMOTENASHI is a lunar lander developed by the Japanese Aerospace Exploration Agency (JAXA), scheduled to launch to the Moon under the Artemis 1 Mission on a NASA SLS Rocket from Cape Canaveral and perform a semi-hard landing in 2022. The OMOTENASHI mission will land the smallest lander to date on the lunar surface.
• 11 NASA CLPS payloads (LETS, MAG, MSolo, NIRVSS, NMLS, NSS, PILS, PITMS, SEAL, LRA, NDL) • M-42 Radiation Detector • 5 Colmena robots • The Terrain Relative Navigation • Iris • Moonark • Memory of Mankind to the Moon • Lunar Dream Capsule • Mementos to the Moon • Lunar Library 2 • Footsteps on the Moon • Lunar Bitcoin • Tranquility Memorial • Lunar Memorial • We Rise Together	Peregrine is a lunar lander developed by the US company Astrobotic, scheduled to launch to the Moon under the Peregrine Mission 1 on a United Launch Alliance Vulcan Centaur Rocket from Cape Canaveral and land closeby the Lacus Mortis in early 2023. If successful, the Peregrine Lander will be the first American spacecraft to land on the Moon since the Apollo program, delivering a record number of 25 governmental and commercial payloads to the lunar surface.

PLANNED DATE	MISSION	ORGANIZATION	LANDER
Early 2023	XRISM mission	JAXA	SLIM Lander
Early 2023	Chandrayaan-3	ISRO	Chandrayaan-3
March 2023	IM-1	Intuitive Machines	Nova-C Lander

PAYLOADS	MISSION DESCRIPTION
• A landing radar to guide its final descent • A multiband camera for mineralogical exploration of the lunar surface	The Smart Lander for Investigating Moon (SLIM) is a lunar lander being developed by the Japan Aerospace Exploration Agency (JAXA), scheduled to launch as a ride-share payload under the XRISM mission on an H2A booster from the Tanegashima Space Center and land near the Marius Hills Hole, a lunar lava tube entrance recently discovered by the Japanese, in early 2023.
	Chandrayaan-3 is a planned third lunar exploration mission by the Indian Space Research Organization (ISRO) consisting of a lander and a rover currently scheduled to launch in early 2023. At present, there is no further information on potential additional payloads that may be carried on this lander.
• Lunar Node 1 Navigation Demonstrator • Stereo Cameras for Lunar Plume-Surface Studies • Low-frequency Radio Observations for the Near Side Lunar Surface • Laser Retro-Reflector Array • Navigation Doppler Lidar for Precise Velocity and Range Sensing • EAGLE Cam • ILO-X • Lonestar Lunar • Lunagram • Moon Phases Art Cube • Omni-Heat Infinity	Nova-C is a lunar lander developed by the US Company Intuitive Machines, currently scheduled to launch under the Intuitive Machines 1 mission on a SpaceX Falcon 9 rocket from Cape Canaveral and land closeby the Mare Serenitatis in March 2023. If successful, Nova-C will deliver a total of 11 governmental and commercial payloads. 5 of the payloads onboard the Nova-C lander have been contracted by NASA under the CLPS. The Nova-C Lander will also carry commercial and scientific payloads.

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PLANNED DATE	MISSION	ORGANIZATION	LANDER
June 2023	IM-2	Intuitive Machines	Nova-C Lander
July 2023	Luna-25 Mission	Roscosmos	Luna-Glob
2024	Chang'e 6	CNSA	Chang'e 6

PAYLOADS	MISSION DESCRIPTION
• Polar Resources Ice Mining Experiment-1 • μNova Hopper • Khon1 • Mobile Autonomous Prospecting Platform • Sherpa OTV • Evolved Expendable Launch Vehicle Secondary Payload Adapter • LO-1	Another Nova-C Lander from Intuitive Machines is scheduled to launch under the Intuitive Machines 2 mission on a SpaceX Falcon 9 rocket from Cape Canaveral and land near the lunar south pole in March 2023. So far the Nova-C is scheduled to deliver governmental and commercial payloads.
• ADRON-LR • LASMA-LR • LIS-TV-RPM • PmL • Thermo-L	Luna-Glob is a lunar lander developed by Roscosmos and currently scheduled to launch on a Soyuz rocket under the Luna-25 mission and land near the Boguslavsky crater no earlier than July 2023. While Luna-Glob's primary goal is to demonstrate Roscomos lunar landing technology, at present the lander is expected to carry science instruments developed in Russia.
• The Detection of Outgassing RadoN • A laser retroreflector • An instrument developed by China and Russia to investigate water ice • An instrument developed by the Swedish Institute of Space Physics to detect negative ions	Chang'e 6 is a complex mission architecture developed and operated by the Chinese Space Administration (CNSA) consisting of an orbiter, lander, lunar ascent vehicle and reentry capsule, currently scheduled to launch on a Chinese Long March 5 rocket from the Wenchang Satellite Launch Center and land closeby the South Pole-Aitken (SPA) basin in 2024. In addition to an undisclosed number of payloads placed by the CNSA, the Chang'e 6 lander is tentatively scheduled to deliver scientific payloads to be potentially developed by international partners.

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PLANNED DATE	MISSION	ORGANIZATION	LANDER
2024	HAKUTO-R Mission 2 (M2)	ispace	HAKUTO-Rt
Late 2024	Griffin Mission One	Astrobotic	Griffin Lander
2024	IM-3	Intuitive Machines	Nova-C Lander

PAYLOADS	MISSION DESCRIPTION
	Another HAKUTO-R lander from the Japanese company ispace is scheduled to launch under the ispace M2 mission onboard a Falcon 9 Rocket from Cape Canaveral and land on the Moon in 2024. According to ispace, this lander has achieved full payload capacity al-ready in July 2022. While the information on payloads to be carried onboard has not been disclosed yet, ispace had previously announced its intention to deliver its HAKUTO micro-rover to the lunar surface as its own payload on this mission.
• Volatiles Investigating Polar Exploration Rover (VIPER) • LandCam-X	Griffin is a medium-sized lunar lander developed by Astrobotic, currently scheduled to launch in 2024. So far two payloads have been manifested to fly aboard the lander, the VIPER rover developed by NASA and the LandCam-X developed by ESA. The main payload flying aboard Griffin is NASA's Volatiles Investigating Polar Exploration Rover (VIPER). The secondary payload is an innovative landing sensor camera, called LandCam-X, developed by the European Space Agency and marking the first commercial delivery to the Moon ever procured by ESA. The Camera will take pictures during landing that will be processed by dedicated algorithms to test and refine European autonomous navigation systems, to improve precision and safety in view of future lunar surface missions.
• Lunar Vertex • Cooperative Autonomous Distributed Robotic Exploration • MoonLIGHT retroreflector • Lunar Space Environment Monitor	A third Nova-C Lander from Intuitive Machines is scheduled to launch under the Intuitive Machines 3 mission on a SpaceX Falcon 9 rocket from Cape Canaveral in 2024. This Nova-C lander will also deliver the second node of IM's Khonstellation, injecting the company's data services satellite (Khon2) to a L2 orbit. This will add to the first node (Khon1), which is currently scheduled to be delivered to a frozen lunar orbit during Intuitive Machines' IM-2 mission.

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PLANNED DATE	MISSION	ORGANIZATION	LANDER
2025		Draper	Draper Series 2 Lander
2025	Lunar Pola Exploration Mission (LUPEX)	ISRO and JAXA	Chandrayaan-4 Lander

PAYLOADS	MISSION DESCRIPTION
• Farside Seismic Suite • Lunar Interior Temperature and Materials Suite • Lunar Surface Electro Magnetics Experiment	The Series 2 is a lunar lander that will be developed by a team lead by the US Company Draper and featuring General Atomics Electromagnetic Systems, ispace technologies U.S. and Systima Technologies. The lander has been contracted by NASA to deliver the following 3 science payloads to the lunar surface in 2025 as part of its Payloads and Research Investigations on the Surface of the Moon (PRISM) call for proposals.
	Chandrayaan-4, also known as Lunar Polar Exploration Mission (LUPEX) is a robotic lunar mission concept by ISRO and JAXA that would send a lunar rover and lander to explore the south pole region of the Moon no earlier than 2025. This lander is currently being designed by ISRO to have a payload capacity of 350 kg at minimum. Under the LUPEX architecture, the lander should carry multiple instruments by JAXA and ISRO including a drill to collect sub-surface samples from 1.5 m depth. Additionally, the Chandrayaan-4 lander is now expected to deploy the Exospheric Mass Spectrometer L-band (EMS-L) developed by ESA under the PROSPECT mission and which was supposed to fly as a payload on the Russian Luna 27 mission.

With these missions in mind, Part Two will now focus on describing the policy implications of the main lunar activities planned in the near future. ◆

02 Payload and Instrument Activities

by Dr. Antonino Salmeri

Payload activities on the Moon encompass a large variety of endeavours conducted by many stakeholder groups pursuing both scientific and commercial goals. While in the early stages the majority of payloads will consist of scientific instruments. The number of commercial payloads is set to increase over time and will likely become prevalent in the medium and long term.

Stakeholder Groups
This section divides stakeholders involved in payload activities between users and providers. Under "users", the section lists entities operating the payloads and benefiting from their activities. Under "providers", the section lists entities providing transportation and landing capabilities needed to bring said payloads to the Moon. Within each category, the section further differentiates the involved actors based on their nature, i.e. between governmental, scientific, commercial and civil society.

Users
Both at present and in the foreseeable future, payload activities on the Moon will be conducted by a variety of users encompassing government agencies, scientific institutions, commercial players and private actors from the terrestrial sector. This section provides a general overview of the kind of entities involved - information about actual payloads operated by these entities is provided in the next section.

Governmental Agencies and Scientific Institutions
At present, the main actors conducting payload activities are governmental agencies, as well as scientific and research entities. The overwhelming majority of payloads scheduled to reach the Moon by the end of the decade are meant to study the lunar environment for a rich diversity of science goals. This is in line with the early stages of lunar development, where the predominant need is to study the Moon and its features to answer key questions on its formation and understand how to operate safely and sustainably. An overview of these payload users includes:

- NASA Ames, Glenn, Goddard, Jet, Johnson, Kennedy, Langley, and Marshall centres;
- Several space agencies in Europe, such as the European Space Agency (ESA), the French Centre National d'Études Spatiales (CNES), or the German Aerospace Center (DLR);
- Space agencies and governmental space centres in Asia and Middle East, such as the Chinese National Space Administration (CNSA), the Japanese Aerospace Exploration Agency (JAXA), Indian Space Research

Organisation (ISRO), and the Mohammed bin Rashid Space Center;
- Research institutes such as the US Southwest Research Institute, the Italian National Institute of Nuclear Physics (INFN), the French Institut de Recherche en Astrophysique et Planétologie (IRAP);
- Universities' Faculties & Labs such as Berkeley's Space Science Laboratory, the Riddle Aeronautical University, Carnegie Mellon University.

Commercial Entities and Terrestrial Private Actors
In addition to governments and scientists, there are also several private entities planning to conduct payload activities for commercial purposes, including ordinary terrestrial users. Thanks to the increase in transport capabilities and the reduction of associated costs, we can expect to see more and more of these stakeholders sending payloads to the Moon for the provision of commercial services. This will be key to the development of a sustained and sustainable lunar economy, which needs to be based on a stable flow of B2B and B2C transactions. An overview of these payload users includes:

- Companies such as Astroscale, Honeybee Robotics, Spacebits, and Elysium Space;
- Non-space private actors such as Bitmex, Columbia sportswear, or The Arch Mission Foundation.

Providers
Both at present and in the foreseeable future, payload activities are enabled by space agencies and commercial companies providing both lander and transportation capabilities from Earth to the Moon. An overview of lunar transportation and landing providers includes:

- *Transportation Providers*
  - Space agencies such as NASA, CNSA and ESA through their launch systems;
  - Commercial companies such as SpaceX, and Blue Origin through their privately owned and developed launch vehicles.
- *Landing Providers*
  - Space agencies such as CNSA;
  - Commercial companies such as ispace, Astrobotic, Intuitive Machines, Draper, Lunar Outpost, Lockheed Martin, and Sierra Nevada Corporation.

In the long term, the development of infrastructure for in-situ manufacturing will add a viable alternative that might even become the primary source for the

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deployment of payloads on the Moon.

Description of Relevant Activities
Currently, the majority of payloads scheduled to be flown to the Moon are meant to pursue scientific objectives, but there are also a number of payloads aimed at delivering commercial products and services on the Moon. The main payloads and the missions they are part of were described in the *Mission Overview,* Section 1. The reader is invited to refer themselves back to it for more information on future payload activities.

Gaps and Grey Areas

Gaps
About a hundred payloads are scheduled to reach the lunar surface over a span of just three years. Two-thirds of them are meant to pursue a variety of science goals, mostly aiming at better understanding the features and physics of the lunar surface and primarily at the request of governmental space agencies or research institutes. In this category, there seems to be no particular lacuna, given the extensive breadth of planned experiments.

The remaining payloads are commercial, meaning that they have been procured by, or contracted to, a commercial entity for non-scientific purposes. The assessment of these payloads varies depending on the time horizon adopted. At present, the overall assessment of commercial payloads scheduled to reach the Moon can be considered satisfactory. This can be explained by the partnerships being developed between space companies and non-space customers for the purchase of services that leverage the spiritual and cultural value of the Moon.

Looking at the medium-term horizon, the situation looks less satisfactory but still not alarming. To enable the development of a sustainable lunar economy, future lunar payloads will have to provide in-situ services such as communications, timing, mobility, power, shielding, and situational awareness. More specific considerations on these aspects will be discussed in the *Infrastructure Activities* chapter.

Grey Areas
The increasing involvement of commercial and non-space actors in the exploration and use of the Moon poses the question of which kind of activities should be allowed thereby. While at present there seem to be enough margins for all interested actors to get involved without prejudice to future uses by latecomers, this may not always be the case. As a result, some actors argue that we should not

fill precious orbital slots or surface locations with objects deemed trivial such as time capsules or funeral urns.

Similar points have been raised by members of the scientific community arguing for the prioritization of science objectives over commercial goals. Specularly to the previous example, supporters of this position affirm the need to study the lunar surface and its environment while they are still pristine, i.e. before the inevitable contamination that will be caused by the increased number of commercial activities. Some actors have supported this position as being fully in line with the special emphasis placed on the freedom of scientific investigation by Article I (3) of the Outer Space Treaty. However, other actors have countered this argument in light of the key role played by private entities and business drivers in reinvigorating global interest in lunar exploration.

Both questions are ultimately related to the broader interrogative of how to allocate the use of the Moon and its locations and resources. While this interrogative is surely not easy to answer, it seems important to at least acknowledge its existence, to avoid the de facto establishment of a first-come-first-served regime.

Precedent-Setting
The deployment of the first commercial payload(s) on the surface of the Moon by the ispace M1 mission, if successful, will set a series of important policy precedents. The main precedents to be set are related to the authorization and supervision of private activities on another celestial body and the conduct of appropriate international consultations in case of potentially harmful interference, respectively under Articles VI and IX of the Outer Space Treaty.

Concerning authorization, the licensing of the first commercial payloads on the M1 mission already established an important precedent about the kinds of activities that can be conducted by private actors on the Moon. If not adjusted in the future, this precedent may lead to overcrowding problems similar to those that are currently affecting low earth orbit.

Regarding supervision, states responsible for said payloads have an opportunity to set the course on how to ensure compliance of private activities with the provisions of the Outer Space Treaty in the absence of technological capabilities for monitoring and/or enforcement in situ. If not corrected, this could result in a laissez-faire approach that could in turn incentivize irresponsible behaviour. Inversely, a faithful partnership between states and operators may validate a self-governance precedent that could increase the credibility of private actors as lunar stakeholders.

Finally, concerning consultations, the presence of many commercial payloads on the lunar surface will provide an opportunity to demonstrate how to conduct appropriate international consultations in case there would be a reason to suspect the occurrence of potentially harmful interference. If done properly, this could determine the establishment of new positive precedents for multi-stakeholder coordination.

Opportunities for Cooperation and Recommendations

The large number of payloads scheduled to fly to the Moon creates many opportunities for cooperation, especially in the field of scientific investigation. The unprecedented data that will hopefully be gathered by science instruments such as PRIME-1, μNova or VIPER has the potential to trigger unparalleled efforts in the study and exploration of the lunar environment. To enable these results, it is recommended that these missions adopt open data policies allowing access to any interested user. Further, existing entities such as the International Space Exploration Coordination Group (ISECG) should leverage their established position within the community to promote global initiatives building upon the findings of pioneering missions.

On a similar line of reasoning, operators of relatively large landers such as Griffin or Nova-C should actively engage in rideshare programs offering the opportunity to smaller actors from civil society or developing countries to participate in lunar exploration by sending a payload to the Moon. Policymakers should promote such behaviours by offering adequate incentives in the form of financial rewards or funding opportunities. At the same time, both operators and policymakers should make sure to allocate available space with due regard to the corresponding interests of other states, avoiding an excessive proliferation of trivial endeavours at the expense of payloads from under-represented groups or pursuing high-level scientific objectives. ◆

03 Orbital Activities

by Jessy Kate Schingler

Orbital activities at the Moon today are predominantly scientific in nature, but also play an important role in supporting surface activities through remote sensing and communications. There is growing interest in developing commercial communication and navigation services. Lunar orbits are easier to access and operate than surface missions, and therefore are likely to participate in the growing interest and activity from less sophisticated and experienced actors.

Stakeholder Groups

Remote sensing scientists are probably the largest users of lunar orbit today. Although there are not currently many spacecraft in lunar orbit, each spacecraft typically has multiple instruments, often operated by different scientists and research groups. A key consideration for this group is the integrity of scientific data. Although each instrument is distinct, factors that are broadly relevant to data quality include vibrations, dust (direct instrument interference or obfuscation of sensing targets), onboard storage, the integrity of the sensing site or environment, and accurate time and/or position information (absolute or relative) about measurements.

Commercial operators and service providers can be expected to seek access to and use particular orbits, as well as the use of specific frequencies. Communication and PNT service customers can be expected to have an interest in the security and integrity of their signals, predictability of the operating environment, lack of electromagnetic interference and in some cases privacy.

The national security establishment has a particular interest in situational awareness and understanding the nature of activities happening in the lunar orbital environment. National program leaders broadly have an interest in fairness and access, and often can be seen to use space to demonstrate leadership and technical prowess, and as a point of national pride.

Use Cases

Lunar orbits are useful for solar system science, remote sensing of the Moon, communication services including positioning, navigation and timing (PNT), and situational awareness activities. In time, they may also be home to platforms offering physical services such as refuelling, storage, or waypoints for extended human campaigns. Studies of the solar system environment have included orbital characteristics and the relativistic/gravitational features and effects experienced in different orbits. Remote sensing science has included gravity, resource, and terrain mapping, using techniques such as spectroscopy, imaging, and precise timing and velocity measurements.

Communication and relay services are nascent but many CLPS missions will deploy relay satellites along with their landers and are planning to offer services to others. There are also several dedicated communication service providers planning to enter the market in the coming years. Both NASA and ESA currently have programs to support commercial lunar communication services, with contracts being offered to support the development and/or act as anchor customers. Communication services will involve data transmission between surface and/or orbital assets to provide bandwidth, act as intermediate storage, and increase coverage such as on the lunar far side which has no direct line of sight to the Earth. PNT utilities include clock synchronization and positioning services to aid in precision measurements, coordination between different activities, and navigation on the lunar surface.

In recent years there has been an emerging interest in situational awareness around the Moon. In part this is motivated by the long-theorized possibility of hiding assets, including offensive satellites, in orbit around the Moon, to be deployed by surprise to lunar or geostationary orbit. This possibility derives from energetic efficiency combined with the large volume of space around the Moon which makes situational awareness difficult. The development of situation awareness capabilities is likely to involve a combination of remote observations from Earth, and assets in situ in the lunar orbital environment.

Future orbital activities include plans for NASA's Lunar Gateway, currently targeted for development in the late 2020s. National and commercial services such as refuelling, waystations for crew and supply transfers, and low-gravity transfer points for onward journeys deeper into the solar system have all been discussed, but remain conceptual for now.

Description of Relevant Activities

The following satellites are currently operational in lunar orbital space:

1. NASA's Lunar Reconnaissance Orbiter, launched in 2009 to map the Moon's surface
2. India's Chandrayaan-2 orbiter, launched in 2019 to act as a relay for the Vikram lander (which failed) and to conduct scientific research such as spectroscopy and terrain mapping.
3. China's Queqiao satellite, a relay satellite in a halo orbit around the Earth-Moon "L2" Lagrange point.
4. China's Chang'e 5 orbiter, launched in 2020 as part of a lunar sample return mission. The sample return was completed and the orbiter is on an extended mission, thought to be in a distant retrograde orbit around the Moon.

5. ARTEMIS P1 and P2, launched in 2007 by NASA as part of the THEMIS mission, studying gravitational effects, solar wind, magnetism and other environmental factors affecting spacecraft in these orbits.
6. The NASA-funded private CAPSTONE mission, expected to arrive in a so-called "halo" orbit around the L2 Lagrange point in mid-November 2022.

The region of space near the Moon is characterized by a number of notable features and characteristics that cause it to differ from the orbital space around Earth, defying familiar intuition.

The Moon is gravitationally "lumpy" which leads to predominantly unstable orbits, despite lacking an atmosphere to introduce drag. "Predominantly" means that stable orbits are the exception, not the rule, and "unstable" means that without active stationkeeping (which uses valuable fuel), such orbits degrade. The nature of this degradation depends on the orbit. Objects in unstable orbits around the Moon will eventually crash into the lunar surface.

The other significant orbital features of interest are the Earth-Moon Lagrange points. These are gravitationally balanced points in space which give rise to interesting families of orbits around them. These orbits are not around a planetary body but around the gravitational balance point. Due to the complex nature of orbital motion, there are numerous different orbits around these points with highly varying periods, planes, eccentricity, spatial relationship to and surface coverage of the Moon. Objects in orbit around Lagrange points or other regional orbits will be subject to complex combinations of forces which may draw them into orbits which are simply unpredictable or which escape the Moon's gravitational influence altogether.

Historically, lunar missions have been dominated by scientific activity, but, as mentioned, there is growing interest in characterizing specific orbits manoeuvrability, commercial payload services, and commercial communication and PNT services. NASA's LunaNet project and ESA's Moonlight initiative are working to catalyze communication networks around the Moon through developing standards and funding commercial services, and independent commercial operators are starting to design and pursue funding for their service designs as well.

Opportunities and Need for Coordination

Norms of transparency regarding planned mission orbits and activities will assist with clarity and confidence for government and commercial actors alike. For example, in 2022 the Chang'e 5 satellites moved into an orbit around the

L2 Lagrange point on an extended mission without any public notification. Although the spacecraft is believed to be undertaking basic studies of orbital dynamics and stability, the incident created tension and speculation because the international community was caught off guard.

There is an opportunity to continue developing our understanding of the capacity and characteristics of key lunar orbits. Knowledge about the features and uses of these orbits will inform appropriate levels of coordination, including their capacity. For example, although many of these orbits are spatially quite large (with multiple-week periods) there may be timing reasons why spacecraft get "bunched up" at a certain segment of the orbit. This in turn might affect radio interference, total capacity, and the relative urgency of disposal. Standards for communication services provide an opportunity to increase interoperability, business collaborations, and reduce mission costs for consumers.

Precedent-Setting

Norms and expectations regarding occupancy and use of lunar orbits are beginning to be established. The use of lunar orbits is currently proceeding in a first-come-first-serve manner, whereas terrestrial orbits are allocated via the International Telecommunication Union (ITU) that manages orbital slots, which come with associated costs and expectations regarding disposal and neighbourly conduct. Whether a formal system is warranted and what distinct criteria would be, remains to be seen, but will be at least partially informed by an improved understanding of the natural characteristics of these orbits, as well as the nature of emerging use cases.

Another precedent likely to be established soon is the standards used for communications in the lunar environment. NASA, along with an international community, has been investing in the development of communication and networking standards that they refer to collectively as LunaNet. International agreement and buy-in to shared protocols and messaging formats will also set precedents for the way in which infrastructure begins to be developed in this environment, and likely set the tone around "network neutrality" and collaboration more broadly.

Finally, precedents being set now also include the rights and responsibilities around payloads on private missions and how (or whether) this process is supervised by launching states under Article VI.

Gaps and Grey Areas

One of the main grey areas and unresolved questions regarding lunar orbit activities is the interaction between military and civil activities. Knowing what is considered military activities in orbit, and how these military satellites relate to potential surface assets will be key to defining and organising a lunar policy framework. Similarly, the liability regime for in-orbit actions will need to be clarified to prevent harmful activities in lunar orbit.

A second grey area currently under research by the US government is related to regulations and oversight of individual payloads being flown commercially on lunar missions. Grey areas currently remain regarding responsibility for disclosure and transgressions as payload operators become further separated from the state of registry, launch operator, or host spacecraft.

Potential for Contention or Conflict
The lack of transparency around orbital use and occupancy can become a source of conflict, stoke fears, and create misunderstandings. Similarly, a lack of shared understanding about the nature and capacities of key orbits might lead to contention down the road. In the shorter term, radio frequency interference should be considered as the orbital space becomes more populated with commercial service providers. Finally, the disposal of spacecraft, while not urgent, is something that should be thought of early on when it is easy to set positive precedents.

Recommendations
Adopting norms of coordination, transparency and notification will be key to characterizing the capacity of lunar orbits, their allocation, use and disposal standards. The international community should consider implementing international standards for network communications including traffic relay and message formats. Standards of transparency regarding mission plans and operations would also go a long way to investing in confidence and mutual understanding.

These recommendations do not require international treaties to be created and implemented. Practical implementation plans usually lead the way for these norms of behaviour to be created. Thus, there are many opportunities for industry actors to use a bottom-up approach and coordinate their efforts to create good precedents instead of waiting for states to provide answers. ◆

04 Landed Activities

by Paolo Pino

Landing is one of the most critical operations of lunar missions. About one-third of all the lunar missions carried out in the last 64 years attempted a Moon landing. More than 50% failed. Landing, therefore, constitutes one of the major parting lines between failure and success. But with the increase in lunar activity foreseen for the forthcoming years, landing will be more than the binary discriminator of single missions' fate. Each landing attempt will have increasingly higher implications for all the other past or planned missions. Most importantly, a growing number of landings in the future will be followed by take-offs from the surface, further expanding the challenges lying ahead.

Stakeholder Groups

For scientists and research groups, the selection of the landing site is driven by the scientific goals that a mission must accomplish. Besides this, an intense landing activity in the same region might pose additional risks to their missions, as the instruments might be damaged or scientifically relevant features of the site might be altered – temporarily or permanently – or made inaccessible by other landed assets.

Governments and space agencies might hold strategic interests for specific landing sites, for instance by virtue of their proximity to minerals and volatiles, national or international outposts, permanently shadowed regions, pits, radio-quiet areas, and peaks of eternal light. Some other sites might offer better conditions for telecommunications. To a first approximation, this could be considered generally true for the near side of the Moon. Others might be attractive for logistic aspects in relation to other strategic pieces of space-based infrastructure. An example of this would be landing and take-off sites optimally located to facilitate rendez-vous and docking with the Gateway. In the future, this pool can include optimal sites to reach L-1, refuelling depots, or to insert Mars-bound trajectories. Governments and agencies will also be involved whenever another entity's landing is perceived as potentially harmful or violating obligations and vice versa.

Lander designers and operators will ultimately plan and perform the descent and landing operations which are critical for mission success. In addition to mission objectives, the selection of the landing site for these stakeholders must also consider specific environmental aspects. For instance, the slope of the lunar surface in the site shall be low enough to ensure stability upon touchdown (ideally below 5°). Similarly, such an area shall be large enough to accommodate for the inevitable inaccuracy – in the order of tens of meters – which prevents a perfectly pinpointed soft landing. Geological features such as crater rims are becoming part of computer-vision-aided landing algorithms.

The illumination conditions will be a key input to landing manoeuvres and necessary for energy generation and nominal operations. The availability of telecommunication relays will help in positioning and navigation. All these instances will evolve as technologies mature and as multiple missions start targeting the same landing areas.

Finally, civil society attributes historical and cultural value to lunar missions, and consequently to their landing sites. This means that such sites and the objects that are present should be preserved and that any decision on this will likely stimulate a wide public engagement and debate.

Description of Relevant Activities
For more information on planned lunar activities refer to the *Missions Overview,* Section 1.

Descent and Landing
The descent and landing phases are critical. A major subdivision of landing activities shall be done between crash-landing and soft-landing. Despite the acquired experience and more mature technology for soft-landing, crash-landings and hard-landings shall still be considered relevant for two reasons: in the short term, these landings might still be used for prospecting missions characterizing local soil composition, like the Chandrayaan-1 and LCROSS probes. In the long term, crash-landing might be the preferred debris-mitigation strategy for end-of-life satellites, as already demonstrated in some cases. This will have implications for all the lunar players that will be discussed later.

For soft landings, a spacecraft will have to control their descent using a propulsion system. The thruster exhaust plume can erode the dusty soil beneath the spacecraft, blasting regolith particles at high velocities across the surrounding area. Studies estimated that the region of influence – i.e. the area within which the ejected particles will fall under the effect of lunar gravity – can be as large as a few tens of kilometres depending on the propulsive thrust and the hovering altitude of the lander. This, together with the hovering time, will also determine how many kilograms of dust will be lifted, which will ultimately influence the damage that can be caused to nearby objects. However, studies based on numerical models and empirical evidence show that no significant damage is caused beyond circa 2 kilometres.

Soft-landing also implies the injection of gas exhaust into the lunar ecosystem, which temporarily alters the extremely thin and rarefied gaseous layer that surrounds the Moon. Initial conditions are restored thanks to the natural phenomena of atmospheric loss of the Moon, provided that the loss rate is not exceeded by the injection rate. The implication of this will be discussed later.

Surface Operations
Once landed, different activities can be performed, which will change in nature and cadence over time. Early activities will be a continuation of the exploratory missions accomplished so far by national space agencies, with an increasing presence of private players like the CLPS providers. This translates into relatively small-scale landers deploying small mobility platforms. Payloads carried to the Moon will mostly consist of scientific instruments and technology demonstrations.

Larger landers are being developed like the Human Landing System for crew transport in support of the Artemis program. As these landers are made available, new activities will be enabled such as pilot-scale ISRU testing, large-scale energy generation plants, crew surface mobility, EVAs, habitats and research stations. In turn, this will demand more stringent operational requirements and broader coordination efforts, as will be detailed in the following sections.

Take-Off
Finally, more advanced landers will be able to return to Earth or to depart to other locations, thus freeing landing sites which would otherwise remain permanently occupied. This can be tied to the presence, in close interconnection with landing sites, refuelling stations, spacecraft inspection and maintenance services, and traffic control activities.

Opportunities and Need for Coordination
As illustrated so far, landing activities will pose several challenges. However, opportunities arise where coordination can unlock greater value for all players and lower the barriers to Moon access and development.

The collective interests of the global scientific community, the strategic importance of water and resources that many spacefaring nations acknowledge, and the limitations of current technologies largely constrain the pool of suitable landing sites for many of the forthcoming missions. This requires coordination in the identification, selection, and utilization of these sites in ways that can maximize the benefits for all actors while ensuring the sustainability of lunar activities.

Such coordination efforts can include the implementation and shared use of landing pads and dust containment shields to avoid particle ejection and damage. Before that, sharing information on soil density, particle size distribution, surface morphology and the presence of nearby assets can help mitigate these phenomena and their side effects.

Coordination will also be key to ensure crew safety during and after descent and landing, for instance by preventing other landing or take-off events caused by the projection of high-velocity ejecta. As landing sites might have to be changed unexpectedly for emergencies, the establishment of shared protocols to safely handle similar situations while avoiding harmful interference will be highly beneficial.

Finally, if a very high frequency of landing and take-off events manifests at some point in the future, coordination will also be important to ensure that exhaust gas emissions do not exceed critical thresholds that might compromise the lunar atmospheric conditions that are vital for astronomical observation or – even worse – alter the ability of the lunar ecosystem to restore its initial atmospheric conditions for very long times. Astronomical observation might also be perturbed by the use of radio frequencies by assets landed in the far-side terrains.

Precedent-Setting
Crash-landing satellites at end-of-life without prior coordination or control on the location might result in the unwanted occupation or alteration of sites of interest or harm to other assets.

If both governments and private operators manage to agree on coordinated approaches for landing on and taking off from the Moon we might then see the development of the first lunar ports. Similarly, the high pace at which new landing vehicles are being developed to land on the Moon does not seem to be accompanied by a parallel planning endeavour done in concert with other actors with similar interests to ensure sustainability.

Gaps and Grey Areas
The establishment of safety zones around landed objects is as important as controversial, due to the concerns raised on the compliance of safety zones with the non-appropriation principles put forth by Article II of the Outer Space Treaty. Depending on the landing activity, different safety zones with different operational principles can be conceived, and their duration is limited. However, more research is needed, and new case studies will eventually provide the necessary insights.

This naturally extends to the decommissioning of landed objects – for instance, whether it shall include plans for their removal from the initial site to allow for subsequent visits. Attention shall also be given to potential interference of landing operations with radio-quiet areas in the far side terrains.

Potential for Contention or Conflict
The permanent occupation of strategic sites by landers can be a potential source of contention. For instance, occupying or controlling peaks of eternal light (PEL) or high illumination regions (HIR) can guarantee almost constant access to energy, which can make a difference in one entity's ability to accomplish permanent lunar presence.

Other potential sources of conflict can be interference with descent operations – either in the form of telecommunication interference or disturbance of critical sensor signal – compromising the chances of a successful landing. On the other hand, errors or contingencies in descent and landing operations can cause harm to landed objects.

Finally, ejecta-induced damage to nearby objects, whether these are scientific instruments, heritage sites, or other assets, is another critical point.

Recommendations
Governments and space agencies shall strengthen international collaboration on the selection of high-interest landing sites, working towards the definition of shared sustainable access and utilization frameworks. This might include landing and take-off impact assessments – both in terms of dust ejecta and gas injections – identification of risk-free crash-landing and emergency landing areas, investing in the development of shared infrastructure such as landing pads, berms, beacons to improve the accuracy of descent and landing manoeuvres, transport corridors for goods and crews, and interoperable communication and navigation services such as NASA's LunaNet and ESA's Moonlight.

Lander designers and operators shall adopt measures to reduce plume effects, for instance by optimizing hovering manoeuvres for minimal ejection, by implementing exhaust gas capture or reduction systems, and by using either existing landing pads or instantaneous landing pad deposition techniques. Adopting new radiation-hardened high-performance onboard computers will help leverage high-precision landing algorithms. Plus, lunar maps can be updated whenever a new object lands so that it can serve as a reference feature or relay to improve the safety and accuracy of subsequent landed activities. Interoperable crewed elements can also be essential to increase human safety, for instance by allowing crew emergency departure or turnover with different vehicles. Instrument scientists and research groups shall implement payload design features that mitigate potential interferences and disturbances. Further, data sharing can improve the robustness and significance of all the measurements done in each experiment.

Finally, civil society should actively support decision-makers in defining the best ways to safeguard and valorize cultural heritage sites. ◆

05 Mobility and Interaction Activities

by Dr. Antonino Salmeri

Due to the physics of the lunar environment as well as the concentration of stakeholders' interests in a small group of targeted regions, it is of the utmost importance that actors operating on the Moon are prepared to interact with each other in a safe and non-conflictual manner. The ability to conduct coordinated interactions among lunar operators will provide the lunar community with the necessary means to address key safety issues such as those represented by the ejection of dust, the causation of vibrations or the occurrence of radio-spectrum interference.

Stakeholder Groups
Interaction activities on the Moon will primarily involve governments and operators, with a potential role for international organizations as facilitators.

Governments will be involved on a direct basis whenever lunar activities are conducted by governmental agencies, or due to their rights and obligations under Articles VI, VII and VIII of the Outer Space Treaty whenever lunar activities are conducted by non-governmental entities. Pursuant to these provisions, states are internationally responsible for ensuring that lunar activities conducted by their nationals comply with the rules outlined in the Outer Space Treaty, and for exercising prior authorization and continuing supervision over the missions of non-governmental entities. They are also internationally liable for all damages caused by any lunar object for which they qualify as launching states. Finally, states are entitled to jurisdiction and control over any lunar object for they qualify as the state of Registry.

Operators will be involved on a primary basis whenever they exercise effective control over the related spacecraft, or on a secondary basis whenever they act either as service providers or purchasers. In most cases, they will have to provide their respective governments with the operational information needed to ensure coordination.

A third category of stakeholders might be involved as facilitators of international interactions. This facilitation role might be played, due to their neutrality, by either UN-based agencies and offices or international non-governmental organizations, depending on the preferences of the stakeholders involved. The added value provided by these facilitators would be to act as trusted partners connecting international stakeholders and assisting them in coordinating their lunar interactions.

Description of Relevant Activities
Due to the features of the Moon, we can assume that there will be several

instances in which lunar actors will have to interact with each other.

All states are equally entitled to explore and use celestial bodies. As a result of this, the same area of the Moon might be targeted for use by several states at the same time. These cross-operational conjunctions represent one of the most sensitive and risky interaction events that can be envisaged on the Moon. From a political and scientific viewpoint, it is only normal that stakeholders want to operate close to the most attractive areas on the lunar surface, such as the permanently shadowed regions or the peak of eternal lights. Transiting through an area which is affected by ongoing operations will require a minimum level of coordinated interaction among the actors involved. To the greatest extent practical, it would be advisable to find ways for all interested actors to coexist altogether, rather than relying on first-come-first-served priority rules. From a technical perspective, this coexistence would require extensive coordination among all concerned actors to ensure that their operations can be simultaneously conducted without causing potentially harmful interference.

Gaps and Grey Areas

There are no procedures or mechanisms specifically dedicated to coordinating mobility and interaction activities on the Moon. Even though Articles IX and XI of the Outer Space Treaty provide foundational guidance, the general and a rather vague character of the solutions offered thereby does not meet the minimum threshold required for ensuring safe and sustainable lunar operations.

From a substantive viewpoint, several grey areas need to be addressed, such as the possible determination of non-binary solutions for overlapping uses of the same lunar areas. The implications of the principle of free access to all areas of celestial bodies under Article I of the Outer Space Treaty on the right to transit across regions affected by ongoing operations also need clarification. The implications of the principle of due regard on the conduct of lunar activities, and in particular how to determine the "corresponding interests of other States Parties to the Treaty" will need to be addressed to allow cooperation of different activities happening on the lunar surface. Further, the procedure to be followed for conducting "appropriate international consultations" under Article IX of the Outer Space Treaty will need to be defined. Finally, a standardized tool for sharing information under Article XI of the Outer Space Treaty will need to be developed.

Precedent-Setting

Several interaction precedents will be established over the course of the present

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decade. Such precedents might be for good or for bad depending on the ability of the involved parties to coordinate and coexist in a non-conflictual manner. For example, if an operator fails to properly estimate the impact of its landing activity over a given region of the Moon, we might see the first piece of spacecraft to be impaired, damaged or even destroyed by lunar dust ejecta.

Recommendations
It is recommended that any operator planning to transit through an area currently used by another entity should develop a transit plan proposal outlining the safety risks associated with its passage as well as the appropriate measures required to address them. Depending on applicable licensing conditions, this proposal might be sent directly to the concerned operator or to the licensing and launching states of the transiting actor. In the first case, an operator receiving a transit plan proposal should examine it in good faith and negotiate with the transiting actor the establishment of mutually acceptable conditions for a safe passage. In the second case, a state receiving a transit plan proposal should review it under Article VI of the Outer Space Treaty and then transmit it to the responsible and launching states involved to undertake appropriate international consultations under Article IX of the Outer Space Treaty.

Also, in this case, facilitators can support both operators and governments in all phases of the process. *Inter alia*, they may help operators with drafting their transit plan proposal, act as mediators between the transmitting and receiving operators, as well as assist governments in reviewing transit plan proposals under Article VI of the Outer Space Treaty or consulting about them under Article IX of the Outer Space Treaty.

To better address cross-operational conjunctions, any operator planning an activity on the Moon should proactively investigate, to the greatest extent feasible, whether other entities are already operating in its targeted area. If that would be the case, the operator should reach out to the identified entities to negotiate a cross-operations agreement determining the terms of their operational coexistence on the Moon. Upon successful completion of the agreement, all involved operators should transmit a copy to their respective licensing and launching states for informational purposes. If an agreement is not reached, all involved operators should inform their respective licensing and launching states for their determinations under Articles IX and XI of the Outer Space Treaty. Similarly, if an operator conducting an activity on the Moon becomes aware of the arrival of another entity intending to operate in the same area, it should immediately inform its licensing and launching states for their determinations under Article IX of the Outer Space Treaty.

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Based on the previous reflections, states should identify internationally agreed mechanisms and procedures for notifying and consulting about lunar activities. Said procedural tools would provide the necessary foundations for acquiring more knowledge and understanding about how to operate within the lunar environment, hopefully leading to the development of best practices. After the first years of operations, it would be advisable to consolidate the lessons learned in a leading international document providing foundational guidance for interaction activities on the Moon. ◆

06 Infrastructure Activities

by Dr. Antonino Salmeri

Infrastructure activities are one of the most critical endeavours for the development of a sustained and sustainable presence on the Moon. Infrastructure in this guidebook refers to communication, power, transport, storage, and habitation systems servicing operators to, from and on the lunar surface.

Stakeholder Groups

Providers
It is likely that in the upcoming decades the lunar landscape will be transformed by the establishment of medium to large-scale infrastructure providing communication, power, transport, storage and habitation services to lunar operators.

In line with contemporary trends in the global space community, infrastructure on the Moon will likely be developed by commercial actors through public-private partnerships funded by major space agencies like NASA and ESA. Currently, a few commercial actors have made concrete plans for the development of lunar infrastructures, so far limited to the provision of power and communications services. For instance, in May 2021, ESA selected an industry consortium featuring 8 European companies led by Telespazio to study the development of lunar navigation and communication services under the Moonlight initiative. In June 2022, 9 US companies divided into three groups have been selected by NASA to develop preliminary designs for a nuclear power plant on the Moon. Finally, in August 2022, the US company Astrobotic was awarded a $6.2 million contract by NASA to advance the study of a solar-based power generation and distribution service called Lunagrid.

Users
Any actor planning to operate on the lunar surface has to be able to land and move on the Moon, power its spacecraft and communicate with Earth. As such, any lunar operator could engage with infrastructure providing these critical services as a user.

If the plans mentioned above are to be successful, actors planning their missions to the Moon might decide to adjust their mission requirements to both cut some costs and gain room for other instruments. For example, scientific operators may provide their spacecraft with a small rechargeable battery designed to plug into the Luna Grid power system, instead of developing and using one of their own, thus extending the duration of their scientific mission and further saving space for more science instruments.

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In light of the key importance of the Moon for scientific investigation, it is critical to ensure that lunar infrastructure will be developed in harmony with related interests and objectives. Amongst them, it is important to mention the need for radio silence on the far side of the Moon, the availability of pristine samples from the lunar poles and the respect for ongoing activities studying the geology of the Moon.

In the long term, the development of infrastructure for in-situ manufacturing will add a viable alternative that might further reduce costs and increase participation for smaller actors.

Description of Relevant Activities
As previously mentioned, infrastructure activities encompass a large number of endeavours meant to provide key services for a sustained and sustainable presence on the Moon such as power, communications, transport, storage and habitation.

Power
Power is one of the most important services that can be provided by the dedicated lunar infrastructure. First, without energy plants generating a constant flux of power, most lunar operations will be limited to just one lunar day (14-Earth days), due to the extremely cold temperatures of the lunar night, which can go as low as -220 degrees Celsius. Second, the conduct of large-scale activities like mining or manufacturing will require significant quantities of energy, approximately in the order of 10-20 kWh per operation - an amount that can only be generated and distributed by large plants in situ.

Communication
Communication is a key service that can highly benefit from the development of dedicated infrastructure. The deployment of satellite constellations on the Moon can enable positioning and timing services for high-precision landing and navigation, or Direct-to-Earth communication services for downstream and coordination. From a spectrum-management perspective, having dedicated constellations servicing all lunar actors would ensure more efficient use of the spectrum and reduce the risk of potentially harmful radio interference.

Transport
Transport is another utility that can be provided by the dedicated lunar infrastructure. Current studies reveal that landing and navigating on the Moon will pose several safety issues caused by the irregularity of its surface and the properties of lunar dust. Permanent infrastructure on the lunar surface

in the form of roads and pads can help to address this issue by creating safe paths and squares designed to minimize the risks associated with lunar transportation.

Storage
Storage is a service that might be better provided through the establishment of structures in situ. This kind of infrastructure could support several activities such as the extraction of lunar resources or the deposit of space objects on the lunar surface by providing dedicated structures and spaces for safe storage. Storage infrastructure can also be used for stockpiling non-functional lunar objects, enabling the establishment of salvage yards that can facilitate future repurposing while also maintaining useful areas of the Moon free to be used by other missions.

Habitation
Last but not least, habitation and agriculture are two services that, due to their permanent character, will most likely be provided through specialized infrastructure on the lunar surface. This infrastructure will probably be the last to be deployed due to the fact that its sustained and sustainable functioning requires reliable levels of energy, communication, transport and storage services available in situ. Additionally, habitation and agriculture infrastructures will further require advanced life-support systems for radiation shielding, recycling - and later on production - of oxygen and water, and air pressurization, all services that require a higher amount of time and money to be developed safely on the part of infrastructure developers.

Gaps and Grey Areas
Due to the permanent and invasive character of infrastructure activities, their conduct on the surface of the Moon raises important legal and policy questions such as: is building a permanent infrastructure on the surface of the Moon compliant with international laws? At which point does the establishment of permanent infrastructure rise to the level of de facto appropriation of territory by means of use or occupation? Should the purposes of the established infrastructure and/or its international character be relevant for these assessments? Is there an obligation to share fundamental lunar infrastructure with all actors?

All these questions do not have a clear answer at the moment because they require delicate balancing choices among the principles of the Outer Space Treaty. To prevent the tensions associated with unilateral interpretations, issues related to lunar infrastructure are being addressed through various processes at the multilateral level. For instance, Principle 5 of the Artemis Accords commits Artemis Signatories to “use reasonable efforts to utilize current interoperability standards for space-based infrastructure, to establish such standards when current standards do not exist or are inadequate, and to follow such standards", however, it is important to note that the Artemis Accords are only a series of bilateral agreements and thus do not have influence from the international law perspective. Finally, some of the questions raised by the development of permanent lunar infrastructure will also be addressed by the recently established UN Working Group on the Legal Aspects of Space Resource Activities, which will begin substantive discussions in 2023 and aims to release a set of initial principles for the peaceful, rational, safe and sustainable conduct of space resource activities by 2025.

Precedent-Setting
The development of the first permanent infrastructure on the lunar surface will set a decisive precedent for lunar policy. Depending on how it will be developed, by which actors and for which purposes, it may inaugurate either a golden age of lunar cooperation or a new lunar race aimed at securing the best spots on the Moon.

Another important precedent will be set by using lunar resources to manufacture pieces of infrastructure in situ. Some companies are already developing technologies aiming to turn lunar regolith into bricks for landing pads and have them fully ready by the end of the decade. This precedent will be particularly relevant for the assignment of jurisdiction and control over the newly manufactured entity.

A further precedent that will be set concerns the deployment of communications infrastructure. This is because the use of the electromagnetic spectrum and associated orbits on the Moon is regulated as part of the deep space region of the ITU, which is a residual category primarily governing communications from Earth to deep space.

At present, there are two international programs currently aiming to establish a permanent presence on the lunar surface: the Artemis Program led by the United States and the International Lunar Research Station (ILRS) led by China. Both programs are still in the early stages and, as such, plans for the development of supporting infrastructure have not been finalized or made public yet. However, there is no doubt that they will both need permanent infrastructure for fundamental lunar services. For example, NASA and the U.S. Department of Energy (DOE) have selected three design concept proposals for a fission surface power system design targeting the end of the decade for a first demonstration. Since Artemis and ILRS target the same area and timeframe,

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the establishment of such infrastructure could either become a point of contention, a prompt for coordination or an opportunity for cooperation. The "Lunar Landing and Operations Policy Analysis" recently released by the Office of Technology, Policy and Strategy of NASA recognizes the need for well-thought precedent-setting in these regards and prompts national and international policy-makers to make their decisions accordingly.

Opportunities for Cooperation and Recommendations
The development of essential lunar utilities available to all actors would benefit both spacefaring and non-spacefaring stakeholders. It would benefit experienced space players by allowing them to concentrate more resources on their mission objectives. It would benefit smaller or new actors by removing substantial technological and financial barriers to their participation in lunar exploration.

Because services like power, communications and habitations will be needed by all lunar actors, it would be more effective and efficient to pool resources for the development of shared interoperable infrastructure providing them. For example, instead of competing over the exclusive use of the few available peaks of eternal lights, lunar actors should be encouraged to share the energy produced with each other. This would increase the aggregate amount of available power at a reduced cost, while also avoiding the political and economic setbacks caused by conflicting claims of exclusiveness.

Due to the small size of the Moon and the variable features of its areas, lunar infrastructure should be developed in targeted sites chosen to maximize the service provided while also minimizing the negative impact on the conduct of other activities. For example, lunar landing pads and related infrastructures should be developed in areas where the gravity of the Moon allows for easier landing, such as the equators, and in any case at a safe distance from areas that have been targeted for lunar surface operations, such as the poles, which would increase the success rate of landing and prevent the risk of potentially harmful interference.

Actors conducting lunar infrastructure activities may wish to consider the following recommendations.

First, stakeholders should proactively share information about the development of lunar infrastructure. At a minimum, states should share accurate information on the nature, location, conduct and results of relevant activities under Article XI of the Outer Space Treaty. Industry actors should facilitate this process

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by providing states with relevant information, and should also engage in complementary efforts for sharing additional data of operational nature. Non-governmental actors could support these endeavours by providing an internationally neutral platform to host said additional operational information.

Second, both states and industry actors should explore opportunities for coordination and cooperation related to the establishment of lunar infrastructure. States should make use of the annual meetings of the UN Committee on the Peaceful Uses of Outer Space to consult about their respective plans for lunar infrastructure and prompt the conduct of bilateral/minilateral conversations to peacefully resolve any conflicting overlap and/or explore options for synergies and cooperation as appropriate. Industry actors should coordinate the development of common standards and interfaces to ensure full interoperability. Non-governmental actors could support both endeavours by providing institutional solutions for managed coordination deprived of political connotations and ensuring the protection of intellectual property rights.

Third, states should incorporate inclusivity and equality in their licensing conditions for the development and management of permanent lunar infrastructure. To preserve the exploration and use of the Moon as the province of all humankind and avoid the de facto appropriation of portions of lunar territory, all permanent infrastructure should be open for use by all interested actors without discrimination of any kind. To ensure equality in the exploration and use of the Moon, developing countries and small actors should be allowed to use lunar infrastructure at reduced fees adjusted to their level of financial and technological development.

Implementing these recommendations would extend the beneficiaries of lunar activities, foster equality in lunar exploration and utilization, prevent the de facto appropriation of lunar territory, preserve the exclusively peaceful uses of the Moon and pay due regard to the corresponding interests of all lunar actors, thus ensuring compliance with key obligations from the Outer Space Treaty. ◆

07 Resource Utilization Activities

by Giuliana Rotola and Dr. Antonino Salmeri

The question of lunar resource utilization is heavily debated and is at the forefront of the upcoming commercial and scientific lunar missions. The extraction and use of lunar resources have the potential to ensure the sustainable development of lunar activities and the permanent presence of lunar operators on its surface. To support the development for commercial use of resources-related activities, it is critical to clarify the ambiguities in the interpretation of international rules and to outline the aspects that can, on the one hand, guarantee legal certainty for private operators and, on the other, prevent the creation of commercial monopolies in the development of such activities.

In addition to the legal considerations, other barriers should be overcome to enable the creation of a market in the sector of the use of lunar resources utilization, such as, for example, an assessment of the presence and distribution of such resources, the development of appropriate technologies, the initial investment cost, and the possibility of access to the market for non-space operators.

Stakeholder Groups

Operators who may be interested in resource activities can be grouped into two main groups: governments and space agencies and private operators in the space sector. Governments and space agencies collaborate with private companies to send instruments and rovers to the lunar surface to analyze the resources present in certain areas of the Moon. These partnerships often rely on a private-public partnership model, with the support of governmental agencies, especially in the prospecting phase, aimed at identifying resources which can be used later on for commercial purposes. Alternatively, some private companies are launching their rovers and instruments to perform their studies of lunar resources and create a commercial plan of their own.

Use Cases

Resource utilization in the near future primarily involves scientific missions. The specificities of the lunar surface are still unknown and the scarcity or abundance of certain types of resources (regolith or water ice for instance) are still to be determined before any commercial utilization can take place.

For these reasons, the earlier scientific missions aim to outline the features of any locations where resources could be found, delineate the quantity and type of such resources, the composition of the soil and the possibility of accessing them - all essential details for planning future utilization missions. Prospecting water ice and minerals are the main targets of short-term missions. The extraction of samples and their analysis can provide knowledge of the challenges and opportunities for future commercial and non-commercial missions. Indeed, it is critical to identify the obstacles posed by the locations where the creation of ISRU infrastructures could be envisaged, such as lighting and thermal conditions, as the ability of technologies to efficiently extract resources and reduce the risk of their dispersal in the lunar vacuum depends on it. The first phase of operations related to resources is thus related to developing processes to extract and preserve oxygen, metals, and other resources.

Once those analyses are conducted conclusively, a series of commercial activities can be identified in the upstream operational processes from in-space resource utilization (ISRU). These activities include an assessment of resource availability to create a utilization strategy depending on this parameter, the development of missions for the extraction and extraction of resources; but also in downstream processes, such as the transport of resources, the refinement of materials, the production of final products and their distribution. Therefore, many market segments are potentially involved, and many are the applications that the lunar resources could have. Looking at the short-medium term, in particular, some primary uses can be identified. The following examples are non-exhaustive, and only present the main uses of lunar resources considered today.

Propellant Production
As stated, for example, in the Global Exploration Roadmap (GER), 2020 supplement, published by the International Space Exploration Coordination Group (ISECG), one of the main Lunar Surface Exploration Scenario Objectives is to "Demonstrate in-situ resource production and utilization capability sufficient for crew transportation between lunar surface and Gateway and lunar surface utilization needs." The GER identifies as a Performance Measure Target the production of 50 tons of propellant per year. To this end, the production of oxygen by extracting it from lunar polar water ice or from minerals in lunar regolith will be the first critical step.

Development of Lunar Infrastructures
Through the exploitation of the lunar regolith and the minerals present therein, additive manufacturing technologies could guarantee a sustainable construction of infrastructures on the Moon, limiting the elevated costs of transporting terrestrial materials.

Life Support
The development of human activities will require Oxygen and Nitrogen for life support systems, including breathing, drinking, and food production. However, life support is not considered one of the main drivers for space resources-

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related activities in the short to medium term.

Precedent-Setting
The initial missions of lunar resource extraction and utilization could allow the creation of precedents for delineating elements of private property in space. As already mentioned, the tension between the non-appropriation principle outlined in Article II of the Outer Space Treaty and some national legislation authorizing the use of space resources for commercial purposes has now created legal uncertainty. So, in the next few years, there is the possibility of creating precedents on virtuous models to transfer and manage lunar resources. In 2020, NASA launched an initiative to select companies that could collect lunar resources and transfer ownership to the space agency. Later, the Open Lunar Foundation announced the creation of Breaking Ground, the first Lunar Resources Trust aimed at demonstrating formal and effective institutional management of lunar resources between different stakeholders. As illustrated in the studies conducted by the Breaking Ground Trust, operations in lunar resource utilization could be setting precedents on how information concerning operations, extraction and utilization of resources are shared. In this sense, precedents could be set up for sharing, for example, scientific data. According to the Artemis Accords Section 8, the Signatories to the multilateral agreement commit to the open sharing of scientific data. This commitment, however, is "not intended to apply to private sector operations unless such operations are being conducted on behalf of a Signatory to the Accords".

The way the first missions use lunar resources for commercial purposes will also define the distinction between appropriation and fair scientific use of these resources. Scientists, as well as commercial actors, are stakeholders of the Moon and defining a balance between the fundamental importance of scientific missions and the commercialization of lunar resources will be fundamental to helping build a sustainable lunar environment.

Ultimately, international consultation, coordination and supervision by state actors on their private national operators will be critical at this stage to avoid the creation of negative precedents.

Gaps and Grey Areas
To ensure the safe and sustainable conduct of space resource activities on the Moon we need to close a number of technical, policy and legal gaps.

First and foremost, there is currently a very limited understanding of the distribution, abundance and extractability of lunar resources. This knowledge gap is particularly significant not only from a technical standpoint but also from a policy perspective, considering the associated implications on the development of access and management regimes for scarce vs abundant resources. For instance, if we would discover that the lunar south pole hosts much less water ice than expected, policymakers might decide to opt for a more conservative approach towards its extraction and utilization. A further critical gap that needs to be addressed concerns the overall landscape of planned lunar activities. Information on the nature, location, conduct and result of activities planned on the Moon is scarce and disorganized. In turn, this impedes a realistic evaluation of existing risks for potentially harmful interference as well as the planning of appropriate measures to prevent or mitigate such risks. Due to the political sensitivity of space resources, this lack of minimum information on both planned and ongoing activities increases mistrust and creates the conditions for speculations, tensions and conflicts.

Further policy gaps are related to the features and procedures of authorization and supervision systems for commercial actors conducting space resource activities. Key questions that have to be solved in licensing conditions include how many mining permits can be assigned to the same company, how long they would last, how many resources can be taken and how to prevent harmful interference without violating the principle of free access to all areas of celestial bodies. International policy documents such as the Artemis Accords provide a starting point for a coordinated approach to the harmonious resolution of these questions within the context of the Artemis program. However, as also recognized in the Accords, fundamental questions of interpretation of the Outer Space Treaty will have to be discussed in UNCOPUOS. Throughout all these processes, it is essential to ensure that policy answers can be adjusted in accordance with new and more accurate information that will be acquired in time.

Finally, there are also ambiguities and conflicting interpretations in the legal framework. As underlined in the first section of this handbook, the international framework governing space activities provides the interpreter with more questions than answers. The Outer Space Treaty, while affirming the freedom of exploration, use, and access to space and celestial bodies, outlines some limitations, including the need for the activities to exercise these freedoms to be conducted for the benefit of humankind. It also affirms these activities must not involve an extension of national sovereignty to outer space, thus prohibiting the appropriation of space and celestial bodies. However, the broad and ambiguous nature of international law has allowed for different interpretations, the concrete implementation of which is often entrusted to the national legislator. In the case of space resources, four states have begun to outline a regime to govern their exploration and use by commercial entities. While these efforts can be appreciated for their aim to provide legal certainty to private operators, their scope is limited to administrative provisions of internal nature. At present, none of these regimes provides substantive answers to the questions discussed above, including with regard to the temporal and spatial limitations of space resource activities or benefit sharing. To close these gaps and ensure the rational, peaceful, safe and sustainable conduct of space resource activities in accordance with international law, the resolution of fundamental legal questions has been entrusted to the newly established Working Group on the Legal Aspects of Space Resource Activities. In accordance with its five-year work plan, in 2023 the Working Group will begin to discuss the applicability and implications of the existing legal framework for such activities, assessing the need for additional rules and making appropriate recommendations in this regard.

Potential for Contention or Conflict
Major conflicts could arise due to the concentration of resources in specific locations, leading to contentious uses of those locations. As is evident from the table of future missions in this area, most of the activities planned in the short term will be located at the Lunar South Pole for the identification of existing resources and their potential extraction.

Possible interference could be controlled by coordination and information-sharing procedures on the missions' type, location and duration. In particular, the consultation mechanisms set by Article IX of the Outer Space Treaty and aimed precisely at avoiding harmful interference in the activities of the state parties could be applied.

Recommendations
The importance and sensitivity of technical, policy and legal questions associated with space resource activities warrants a firm but also considerate approach to their resolution. As such, actors and policymakers planning or conducting lunar missions aiming at the exploration and use of lunar resources may want to consider the following recommendations.

Firstly, all actors should openly share fundamental information on the nature, location, conduct and results of their space resource activities. Due to the current lack of standardized procedures and tools, we recommend operators and policymakers engage in the multilateral and multi-stakeholder development of agreed practices for enhanced information sharing related to lunar activities as a matter of priority.

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Second, we recommend policymakers exercise appropriate restraint in the establishment of (provisional) licensing conditions for the commercial recovery and use of lunar resources, as a way to pay due regard to the corresponding interests of others. It is of the utmost importance that pioneering missions do not set negative precedents that may lead to the de facto establishment of a few dominant positions in the access and use of lunar resources.

Third, we recommend operators and policymakers involved in lunar resource activities regularly consult with each other with the view of preventing and mitigating any potential overlap or interference among their planned and ongoing missions. In case such overlap or interference would affect three or more parties, we recommend seeking the assistance of neutral mediators to facilitate their amicable, prompt and mutually beneficial resolution and avoid their degeneration into geopolitical tensions and disputes that may endanger the exclusively peaceful uses of the Moon.

Fourthly, we recommend operators collectively engage in the development of minimum standards for the evaluation and prospecting of lunar resources to ensure consistency, accuracy, transparency and verifiability of reported information. In conjunction with the development of the suggested standards, we recommend the conduct of an internationally coordinated lunar resource evaluation campaign for the confirmation of current orbital data on the existence, abundance, distribution and extractability of ice in the Lunar south pole, to provide the level of certainty needed to enable investments and regulation.

To solve some of the uncertainties related to the legal aspects connected to resource extraction, utilization, and processing, COPUOS created the WG mentioned above on Space Resources. Although COPUOS could be criticized for the limited inclusion of non-state actors in the decision-making processes and discussions, there is a new open opportunity to interact with the WG and provide inputs on different aspects of the issues, including but not limited to: the views of stakeholders regarding the existing legal framework for space resource activities, the current practices and challenges in the implementation of the existing legal framework for such activities, the benefits and challenges to the development of a framework for such activities, and the relevant factors for the development of a set of initially recommended principles for such activities. Hence, it is recommended to interact with the WG should there be new opportunities in 2023 to submit relevant comments and suggestions. ◆

08 End of Life

by Michelle Hanlon

Already, there are more than 110 sites on the Moon where you can find equipment and objects from missions that have been completed from the Luna 2 which hard-landed in 1957 to the Chang'e 5 lander left behind at the close of China's successful lunar sample-return mission in 2020. Nevertheless, neither international law, including various soft law instruments nor any national laws or regulations directly address what should happen to objects left behind on the lunar surface when a mission is complete. This raises immediate questions about the sustainability of lunar operations: what should we do with these objects which no longer serve a useful purpose, especially if they are located in areas that can potentially support alternate operations?

As a preliminary matter, it is necessary to underline that the provisions of the Outer Space Treaty reach private space activities through Article VI which makes states internationally liable for the activities of even non-governmental entities. Thus, even if your government does not have any regulations in place regarding end-of-life – and as noted, as of this writing none do – your activities may violate international law. Unfortunately, the Outer Space Treaty offers conflicting guidance. Article I is clear that "there shall be free access to all areas of celestial bodies." Article II affirms the concept of free access by prohibiting national appropriation of the Moon "by means of use or occupation, or by any other means." And Article XII indicates that all "stations, installations, equipment and space vehicles on the Moon shall be open" for visits on a basis of reciprocity.

Conversely, Article VIII is clear that a state retains jurisdiction and ownership of objects "landed or constructed" on the Moon, "including their component parts." This means that your state retains jurisdiction and control of, and responsibility for, an object essentially in perpetuity. Read together with Article VII, which imposes international liability for damage done to an object in space, mission activities are protected as damaging operational equipment would allow for the victim to seek compensation, albeit through respective governments. However, when the mission is complete, there would, arguably, be no compensable damage done as the instruments would ostensibly no longer be operable.

Article IX of the Outer Space Treaty provides the only restriction on the concept of free access described in Article I: first, activities in space must be carried out with "due regard to the corresponding interests of all states;" second, activities on the Moon must be conducted in such a way as to avoid its "harmful contamination;" and finally, parties must take part in consultations if it is anticipated that their proposed activity will harmfully interfere with another.

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This framework allows for any entity to simply leave its detritus behind at the end of a mission. Indeed, it has been estimated that there are more than 400,000 pounds or 180,000 kilograms of material already left by humans on the Moon ranging from rocket bodies to urine bags. Should we continue in this manner, it is not difficult to foresee a Moon crowded with junk, a future compounded by the offer by certain companies to deposit private mementoes – and even human ashes – on the lunar surface for the right price.

Stakeholder Groups
This trend must raise flags to anyone interested in pursuing activities on the Moon whether commercial, scientific, educational, aesthetic or even personal. But its reach is far more insidious than that. The question of end-of-life has deep implications for all humanity in respect of, among other things, intergenerational equities, both past and future. Future generations should have the right to inherit the same diversity and access to resources on the lunar surface to include tangible and intangible cultural and natural resources. The achievements of past generations should be memorialized and celebrated. Humanity's first steps off our home planet of Earth remain, at this time, relatively unscathed due to the lack of weather and human activity on the Moon. Our first lunar landings, both robotic and human, represent humanity's greatest technological achievement and the culmination of the work of centuries of human cultures across generations, geographies and disciplines that have contributed to our understanding of astronomy, physics, propulsion, and so much more.

As such, not only must we query what we will do with what we consider to be garbage or debris, we have to question what must be protected as human heritage and what may be recycled or salvaged.

Description of Relevant Activities
What to do at the end-of-life of a mission is a question that implicates any activity on the lunar surface including any impact events, both intended and unintended. Thus, objects in lunar orbit and even objects that may impact the lunar surface must also be considered. Indeed, in March 2022 an unidentified rocket, believed to be part of a Chinese Long March 3C launched in 2014, crashed into the Moon. These end-of-life concerns are raised regardless of the purpose of the original mission.

Opportunities and Need for Coordination
End-of-life considerations are also ripe for coordination and collaboration. We can borrow from two well-recognized regimes widely adopted here on Earth: maritime tradition and heritage protection.

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Much can be learned from the long tradition of maritime salvage, which dates from the ancient Phoenicians, Greeks, and Romans. To deal with human-produced sea perils, commercial "salvors" were and still are rewarded financially for rescuing ships and their cargo, clearing shipwrecks from shipping lanes, and eliminating or preventing other environmental hazards. Historically, commercial salvors were rewarded only if they met three conditions: (1) the vessel or cargo must be in peril; (2) the salvor must be acting voluntarily and under no contract existing before the peril; and (3) the salvor must be successful in its efforts ("no cure, no pay"), although payment for partial success was traditionally granted under certain circumstances.

Salvage tradition until 1980 only recognized a ship, cargo on board, freight payable, and fuel carried on board as subject to salvage, if in "peril," defined broadly. However, the concept of special compensation beyond pure property salvage for preventing environmental damage was codified and expanded by the International Convention on Salvage, 1989 (Salvage Convention), which entered into force in 1996. Article 14 of the Convention considers the protection of the environment (even beyond oil spills, for debris) as part of salvage and therefore subject to reward if contamination is prevented by the salvor. Such reward, informally called "liability salvage," is officially termed "special compensation" by the Convention, as opposed to compensation for property salvage. Because acquiring "special compensation" under Article 14 of the Salvage Convention proved to be time-consuming and somewhat limited, an alternative system for awarding special compensation, known as the Special Compensation Protection and Indemnity Clause (SCOPIC) was developed by Protection and Indemnity (P&I) Clubs, salvors, underwriters, and ship owners.

Adopting and promoting a tradition of lunar salvage would both incentivize recycling and promote sustainability. It would also support another economic opportunity on the Moon and also offer a foundation for sustainability on other celestial bodies and our Low Earth Orbit.

But even before salvage we must consider how to identify, and curtail the abuse of labelling, objects that should be protected for their universal value to humanity. The World Heritage Convention protects our human heritage here on Earth in part because it is well-understood that global recognition helps to build a sense of community among peoples throughout the world. This sentiment must be preserved and promoted as we build human communities on the Moon and beyond. The Artemis Accords, signed by 21 states as of this writing, enshrines the principle of protecting heritage in Section 9 which avers that "Signatories intend to preserve outer space heritage, which they consider to comprise historically significant human or robotic landing sites, artefacts, spacecraft, and other evidence of activity on celestial bodies in accordance with mutually developed standards and practices." The key to this provision is that standards and practices must be mutually developed to prevent abuse.

Precedent-Setting
Simply relying on avoidance could set a dangerous precedent and build an understanding of due regard to mean that objects in situ will always take precedence and quasi-territorial claims will become recognized, allowing for a sustained first-mover advantage. Conversely, implementing the plain meaning of Article I - free access to all areas of the Moon - could seriously hamper investment and development as disputes will no doubt arise as to how to determine if in fact, an object is at the end of its mission and who should be making that decision.

Gaps and Grey Areas
The legal conundrums posed are generally applicable to all missions and could result in wasteful litigation. Leaving behind detritus could arguably violate Articles I and II of the Outer Space Treaty as left-behind objects are blocking "free access" and may be seen to be claiming territory "by occupation." Conversely, the objects remain under the jurisdiction and control of your government (Article VIII) and should another entity attempt to move or recycle them, you will have the opportunity to make a colourable claim for damages (Article VII) or violation of the principle of due regard (Article IX). Of course, others can also claim that you have violated the principles of due regard, harmful contamination and harmful interference by leaving your debris behind.

Potential for Contention or Conflict
In the short term, it may be easy to avoid discord so long as those engaged in activities on the lunar surface are transparent with respect to their locations, allowing others to avoid them. However, this can set a dangerous precedent in and of itself and can be corrupted into quasi-territorial claims. Imagine, for example, that a lunar probe has discovered copious amounts of water in a certain location but the company that initially sent the probe has dissolved and is not in a position to extract the resource. The relevant state may take the opportunity to claim that the probe cannot be removed, preventing others from reaching the water. Taken to the extreme, the state may also aver that the object should be treated as cultural heritage and impose a no-traffic zone around the object, preventing passage within a one or two (or more) kilometre radius.

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Recommendations
In practice, the primary recommendation is that parties coordinate to assure effective recycling and reuse opportunities. Building bilateral salvage and reuse agreements could ultimately result in a tradition of salvage similar to that developed in maritime law.

A second recommendation is to support the concept of heritage protection zones. The concept of such a safety zone is not unprecedented. Russian law indicates that "rules may be established" to guarantee the security and safety of a space object. NASA has issued voluntary guidelines requesting that consideration and due regard be given to historic landing sites. While protecting sites of historical significance is vitally important, the practice can also easily be exploited. Any nation or entity can make claims as to the historic importance of any object left behind on the Moon. The international community must agree to protocols on the identification of heritage objects and sites to assure that the practice is not abused unilaterally.

Nevertheless, in many ways, the concept of heritage protection is the "low-hanging fruit" which can serve as the backbone of lunar governance. Placing culture at the heart of development policies is the only way to ensure human-centred, inclusive and equitable development. Culture is who we are, where we have been, and where we are going. It is what shapes our identity as humans. In short, development cannot be sustainable without culture. Moreover, cultural heritage protection is a mainstay of intergenerational equity. The protection and preservation of human heritage recognizes those who came before us, protects the gains of our civilization and allows future generations to learn from both their results and their processes. It reminds us that we do not stand on a starting line as we look to space, we stand on the shoulders of those who came before. In protecting cultural heritage we are drawn together in kinship rather than drawn apart by barriers and we assure sustainable rules and sustainable development. Focusing first on the development of cultural heritage protection zones around agreed-upon historic sites, like Luna 2, Apollo 11 and Chang'e 4, provides the baseline for a legal model that promotes kinship rather than competition and protection rather than exploitation. This will assure the sustainability of both the rules themselves, and the activities and resources they will guide. ◆

Afterword

by Martin Elvis, Center for Astrophysics | Harvard & Smithsonian

———Back in April 2020 when I gave what, I was surprised to learn, was the opening talk of the Moon Dialogs series, I had just stumbled into Moon policy. As an astrophysicist it was natural to talk quantitatively about the distribution of resources and where conflict might arise from that far-from-uniform distribution. As an outsider it was also clear that lunar policy was in an embryonic state. Yet the issues were urgent: within a decade, conflicts over concentrated resources would be beginning. The Moon Dialogs fulfilled a need. They covered a wide range of expertise and viewpoints. In doing so, the Salons created a community with a common knowledge base. The result is this *Lunar Policy Handbook*, that describes the situation in language that is readily understood by anyone with a serious interest in the subject. The Handbook presents the facts; it does not try to prescribe solutions but does try to ensure than any solutions that are adopted are well informed.

———The Moon Dialogs series continued and developed every full moon for a year and a half covering many specific use cases in depth. By the end there was enough accumulated information and insight that it would obviously be useful to bring it all together. Part Two of the *Lunar Policy Handbook* tackles all these use cases one by one so that any would be lunar user can quickly get up to speed on the situation closest to the one they will face. No doubt this will be just the first edition of the *Lunar Policy Handbook*. As we learn more granular detail about the moon and its resources, as will be needed to actually make use of them, and as we

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gain more experience from the first movers, the questions posed here will sharpen up and can be addressed more precisely in new editions of the *Lunar Policy Handbook*. I'm looking forward to the rapid changes about to come. ◆

Further Reading

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Treaties

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- Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, 1968
- Convention on International Liability for Damage Caused by Space Objects, 1972
- Convention on Registration of Objects Launched into Outer Space, 1976
- Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, 1984

UN Declarations and Resolutions

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