GEGSLA

ANNEX I - Technical Guidelines for Implementation of the Recommended Framework

&

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GLOBAL EXPERT GROUP ON SUSTAINABLE LUNAR ACTIVITIES

GEGSLA Chair's Explanatory Note

In addition to participating plenary discussions, the members of GEGSLA also formed four sub-groups. Under the instruction of the Chair, subgroups worked intensively through regular meetings to advance topics which are developed in the plenary. The outcome of the sub-group deliberations was compiled in a separate document titled *Technical and Operational Practices and Case Studies on Peaceful and Sustainable Lunar Activities*. Furthermore, upon the Chair's suggestion, the observers of GEGSLA through their collective efforts identified *A List of Future Issues of Sustainable Lunar Activities* which are not covered by the Recommended Framework and Key Elements for Peaceful and Sustainable Lunar Activities, and recommended it for further discussions at a later stage.

The Chair on behalf of the Bureau of GEGSLA thanks the members of the sub-groups and observers for their efforts to rich the evidence base and to further the perspective of our joint initiative towards peaceful and sustainable lunar activities, and takes the liberty to share the aforementioned two documents with interested lunar stakeholders.

The Chair would like to note that due to time constraint, GEGSLA did not have time to discuss aforementioned two documents, therefore they should be treated as separate and independent from the Recommended Framework and Key Elements for Peaceful and Sustainable Lunar Activities which was adopted by the GEGSLA plenary in consensus.

Introduction

The **Annexes I and II** are organized as follows:

Annex I (Technical Guidelines for Implementation of the Recommended Framework), assigned to Members, with the participation of Observers in working groups, covers technical guidelines around 4 parts: Lunar Information Sharing, Safe Operations and Lunar Environmental Protection, Interoperability, and Lunar Governance.

The Lunar Information Sharing part offers templates and protocols for supporting lunar actors in the global development of consistent LIS practices, together with a case study including the potential establishment of safety zones.

The Safe Operations and Lunar Environmental Protection part covers 3 sections, on Safety Zones, Heritage Protection, and Debris Mitigation and Environmental Sustainability.

The Safety Zone section recommends the establishment and public notice of Safety Zones when conducting lunar activity. While defining precise criteria for Safety Zones notice procedures, objectives, information, and consultation mechanisms, it is emphasized that Safety Zones are purely informational, have no inherent legal effect, and are subject to the principle of free access under international law. Furthermore, they should be updated if activities change and, being temporary in nature, should be terminated when activity is concluded.

The Heritage Protection section is briefly introduced then further developed in a reference document that can be found on the MVA webpage. Lunar Heritage sites fall under two categories, cultural and natural: a lunar cultural heritage site is any place with human material culture on the Moon or that is associated with intangible practices, representations, expressions, knowledge, or skills, that has historic, social, aesthetic, spiritual, or scientific significance for present and future generations. A lunar natural heritage site is any place, geological or landscape formation that has historic, social, aesthetic, spiritual, or scientific significance for present and future generations.

The Debris Mitigation and Environmental Sustainability section is developed then further enriched by technical recommendations developed in a reference document that can be found on the MVA webpage. Debris Mitigation covers both human-made and naturally created debris. Environmental Sustainability includes the ability to maintain the conduct of space activities on and around the Moon indefinitely into the future. Its practice is defined in a manner that realizes the objectives of equitable access to the benefits of the exploration and use of outer space for peaceful purposes. This is conducted in order to meet the needs of the present generations while preserving the outer space environment for future generations.

The Interoperability part refers to the development of common standards of design, manufacture and construction and/or operations to enable software and hardware components to be interchanged or operated in conjunction, to facilitate international cooperation, recycling and repurposing. It covers a around a dozen technical categories that are Avionics and computer components, Communication and navigation, Rendezvous and docking systems, Outboard robotics, including lunar equipment, Training of mission crews, Harmonization of training methods in terms of safety, Space Debris Disposal, Mechanical, Pneumatic-Hydraulic, Electric, Power Supply Systems, Safety Support Means of Crewed Missions, and Deployment Systems.

The Lunar Governance part defines governance as systematic and comprehensive management and decision making on issues related to the full range of lunar activities, consistent with the principles enumerated in the Outer Space Treaty and other relevant aspects of international law. Through multi-stakeholder engagement and dynamic interactive processes, lunar governance will enable the sustainable exploration and use of the Moon. Governance is the sum of all the ways through which members of the global society manage shared problems. It is a mean to promote cooperation between members and a process capable of producing effective results in the management of global issues. By expanding the definition of governance from Earth affairs to Moon activities, lunar governance is concerned with management of shared problems related to the use and exploration of the Moon and should be developed to ensure peace and security in outer space, to maintain the sustainability of lunar activities, and to benefit all humankind. After reviewing stakeholders and essential elements of responsible lunar governance, instruments for developing it and processes to implement it are being defined.

Annex II (Future Issues), assigned to Observers, contains a summary listing of matters pertaining to the peaceful, safe, and sustainable development of lunar activities, which, whilst not being assessed in the technical guidelines in the Recommended Framework Document main body and Annex I, nevertheless would require some international agreement, but not in the timeframe envisioned under the Recommended Framework document. These matters will therefore remain to be resolved in a later time frame. The contents of this Annex are not intended to overlap with matters considered in Annex I, and are deliberately limited to only a brief description and possible implications, carrying no implied priority order.

Finally, several directing principles have been guiding this work all the way:

a) This is a living document. It will evolve over time and will probably be revisited yearly.
b) This work is conducted in a collaborative and inter-disciplinary manner. It should be accessible and digestible by all, avoid using jargon, and it will be edited where necessary.
c) All participants have tried to anticipate many situations that will happen in coming decades of lunar activities, while putting forward mechanisms to mitigate what could possibly go wrong or become unsustainable.
d) Participants are also mindful of the fact that, until a clearer picture of lunar activities emerge, premature regulatory efforts may backfire, either by proving irrelevant, missing out on important cases, or stifling innovation.
e) At the same time, regulatory certainty is required in order for investors, major operators, and venture businesses, to be able to focus with more predictability on sets of solutions.

It is the intention of all participants for this work to contribute to support the development of lunar business, legal, and technical architectures, while enabling proper pathways for safe, peaceful, and sustainable governance of lunar activities, for the benefit of all humankind.

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ANNEX II - Future Issues

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ANNEX I

Technical Guidelines for Implementation of the Recommended Framework

PART A: Lunar Information Sharing

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Introduction

Few contests that information sharing will play a critical role for the safety and sustainability of lunar activities. In this document, Lunar Information Sharing (LIS) is defined as the exchange of data about lunar activities among all stakeholders involved, carried out either under legal obligation, with the agreement of the involved parties or on a voluntary basis, as well as the wider dissemination of lunar data for the benefit of humankind. To the greatest extent practicable, information shared should be accurate, up to date and adequate for its purpose.

This document is divided into four sections. Section 1 gives a general overview about LIS by discussing foundational aspects such as its goals, object, actors, time and process. Section 2 offers templates and protocols for supporting lunar actors in the global development of consistent LIS practices. To complement this analysis, Section 3 presents a case study based upon an hypothetical scenario of private lunar operations, with special consideration to the potential establishment of safety zones as well as the limitations posed by intellectual property rights or national security concerns. Finally, Section 4 concludes the document by considering the way forward for the development of databases and institutions for hosting and reviewing information shared.

Section 1 - LIS Essentials

This section provides an overview of the essential components for effective and adaptive LIS.

1.1. Working definition

For the purposes of this document, Lunar Information Sharing (LIS) is defined as the exchange of data about lunar activities among all stakeholders involved, carried out either under legal obligation, with the agreement of the involved parties or on a voluntary basis, as well as the wider dissemination of lunar data for the benefit of humankind. To the greatest extent practicable, information shared should be accurate, up to date and adequate for its purpose.

1.2. Rationale

In our discussions we have identified the following main drivers for LIS (in no particular order):

u) Transparency, to promote confidence-building and preserve peaceful purposes.
v) Safety, to enable due regard and prevent potentially harmful interference.
w) Coordination & cooperation, to support interoperability and enhance sustainability.

1.3. Legal basis

We recognized the applicability of the following legal sources to Lunar Information Sharing:

- The Outer Space Treaty, and in particular its Article XI;
- The Registration Convention.

We also recognized the importance of the following UN resolutions:

- UNGA Resolution 1721 (XVI) B (International Cooperation in the Peaceful Uses of Outer Space)
- UNGA Resolution 61/101 (Recommendations on enhancing the practice of States and international intergovernmental organizations in registering space objects)

1.4. Relevant Stakeholders and associated responsibilities

Sharing information about lunar activities is inherently a multi-stakeholder process. Pursuant to relevant norms of international space law, UNOOSA should be prepared to receive, organize and disseminate information received from States immediately and effectively. It is recommended that the following stakeholders might be involved as main focus: States, Operators, and Civil Society.

- *States*

Based upon applicable norms of international space law, States might be required to share information about their space objects and/or space activities with UNOOSA, other States, the general public and the scientific community.

- *Operators*

Based upon applicable norms of national space law and regulations, operators may be required to share information about their space objects and/or space activities with their licensing State.

- *Civil society*

On a voluntary basis, civil society organizations might support information sharing by developing and managing complementary databases for hosting additional information as either provided by operators or other reliable sources within the space community.

1.5. Issues, Hurdles and Obstacles

Needless to say, information sharing is not a completely uncontroversial endeavor. From our assessments we have identified the following issues, hurdles and obstacles.

- *Political Issues*

Political issues within the global arena might negatively affect information sharing among States. However, given that lunar activities are not about security and intelligence operations, States could be persuaded to see that there are in fact positive benefits from information sharing. Knowing what others are engaged in and removing suspicions could prove to be beneficial in the long run.

- *Social Hurdles*

Lunar activities as flagship projects of many spacefaring nations also come with significant social, cultural and political connotations, which might further complicate their calculation on whether and how to share information. Reiterating that space is part of the global commons and that states and other stakeholders all stand to benefit from information sharing could slowly open up states to engage in openness and transparency measures.

- *Intellectual Property & National Security Obstacles*

Intellectual property rights and national security concerns can significantly hamper the process of information sharing. Therefore, it is essential to prevent the abuse of these clauses as an *a-priori* obstacle to information sharing. More on these topics will be discussed in Section 3.

1.6. Key principles of Lunar Information Sharing

From the above analysis we can derive the following key principles for LIS:

- *LIS is a (critical) means to an end*

With information sharing we can achieve fundamental goals of international space law.

- *One size does not fit all*

Different purposes require different content and processes.

- *LIS is a multistakeholder effort*

Public and private actors need to be involved at different governance levels.

- *LIS is a benefit, not a burden*

Without information sharing we cannot protect activities from interference and conflicts.

- *Effective LIS requires follow up*

We need institutions to share, consult & conciliate on a stable and continuous basis.

- *The whole is more than the sum of its parts*

Centralized information on lunar activities could open new markets and opportunities.

Section 2 - Operational guidelines for LIS

This section provides suggested guidelines for the practical benefit of lunar operators. Subsection 2.1 presents suggested content and processes for achieving the various purposes of lunar information sharing. Subsection 2.2 discusses proposed templates and protocols to support pioneering operators in the global development of common practices for lunar information sharing.

2.1. Suggested content and processes

This subsection presents suggested content and processes for achieving the various purposes of lunar information sharing.

- *LIS for Transparency*

  Minimum content:

  - Nature of the activity (scientific or commercial; human or robotic; exploration or use)
  - Envisaged landing area and duration (start – end)
  - Space objects and/or humans involved (with description, e.g. rover, crew, tourist)
  - Contact information for consultation requests

  Envisaged processes:

  - Notification to the UN Secretary General under Article XI OST;
  - Public announcement:
  - Further information sharing via relevant international fora;

- *LIS for Safety*

  Minimum content (potentially under NDA):

  - Fundamental mission parameters, such as:
  - Nominal area of operations (including exact lunar coordinates);
  - Nominal evolution of operations (including envisaged changes in locations).
  - Safety impact assessment, such as:
    - Harmful consequences of operations (e.g. dust creation, radio-interference);
    - Vulnerabilities of operations (e.g. exposure to dust, sensitivity to vibrations);
    - Mitigation measures (e.g. safety/coordination zones).

  Envisaged process:

  - Article XI OST, *ad hoc* transmission upon motivated request from interested States.

- *LIS for Coordination & Cooperation*

  Minimum content:

  - Scientific discoveries (e.g. lunar surface composition, conditions of environment);
  - Technical parameters for systems' interoperability;
  - Lessons learnt from lunar operations for developing standards & guidelines.

  Envisaged process:

  - Public dissemination through media, contribution to lunar database.

Section 2.2. Proposed Templates & Protocols

To complement the previous suggestions on content and processes, this sub-section presents proposed templates & protocols to support pioneering operators in the global development of consistent practices for lunar information sharing.

- *Templates*

The development and use of templates for lunar information sharing might play a critical role in facilitating and streamlining the global development of best practices. To this end, this Annex would like to recall the pioneering work conducted in this area by individual GEGSLA Members within the context of the Article XI Project for the uniform application of an innovative Template for Sharing Information under Article XI OST.

- *Protocols*

Currently, the global landscape for information sharing is significantly fragmented. Each actor values information sharing in a different way and consequently adopts different approaches in undertaking it. This lack of minimum harmonization prevents the optimal use of information and might represent a critical risk to the immediate safety and long-term sustainability of lunar activities. To mitigate such a risk, this subsection provides a step-by-step process that lunar operators may wish to consider for the consistent development of global best practices in the area of information sharing.

a) Phase 1: Preliminary Assessment

First of all, all operators involved in lunar activities should appoint a Chief Information Officer (CIO) to create and manage relevant internal processes as well as coordinate with external stakeholders and partners.

Following, operators should engage in knowledge gathering, surveying the current landscape for information sharing as provided either in public sources or ad hoc consultations with experts and other operators. The discovered knowledge should then be used to conduct a preliminary SWOT analysis on the strengths, weaknesses, opportunities and threats of LIS for the given operator.

a) Phase 2: Documentation

After completing the SWOT analysis, operators should conduct an information audit to identify the types of data concretely produced by the organization and subsequently develop an internal repository. These data should be then categorized based upon their content, internal strategic relevance and external usefulness. As part of this process, operators might want to follow the well-known FAIR model, according to which data should be Findable, Accessible, Interoperable and Reusable.

a) Phase 3: Strategy

Combining the results of the SWOT analysis with those of the internal information categorization, operators could develop a strategy to govern their LIS engagements in accordance with their legitimate interests and in compliance with applicable legal obligations. This strategy should lead to the development of guidelines for the internal collection and external dissemination of information through the establishment of disclosure levels and related procedures. These guidelines should be tailored to the specific purpose of information sharing (among the three identified in the previous section) as well as to the relevant target audience. The strategy should also foresee the development of post-release evaluation mechanisms for continuous improvement, as well as the inclusion of a public point of contact for any question, request for consultation or opportunity for cooperation.

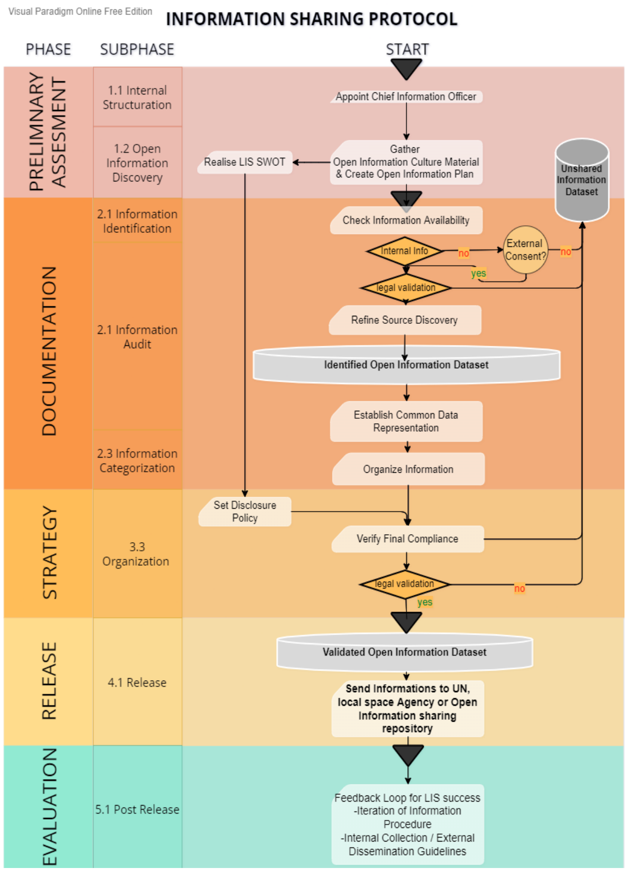
a) Phase 4: Release

In accordance with their dissemination guidelines, operators should release information based upon relevant disclosure levels and procedures, included but not limited to regulated disclosure of validation information as part of the exploration, mapping, and licensing processes. These processes may be required to quantify economically extractable reserves out of assumed resources, making that information available to relevant stakeholders.

a) Phase 5: Evaluation

Finally, operators should build a feedback loop for evaluating the success of their LIS engagements in accordance with the goals and procedures laid down in their strategy. This should include dedicated mechanisms for the concrete modification of the strategy itself, as well as of the internal collection and external dissemination guidelines.

The flowchart below summarises the above-described phases in a visual manner.



Finally, the table below provides four strategic goals for the development of an Open Information Culture that might facilitate the implementation of the above protocol on LIS. Each strategic goal is designed to be specific, attainable, targeted and measurable. The table further defines strategic objectives as clear descriptions of the main actions that must be taken to achieve each goal. They are designed to be the “bridges” that take operators from where they are today to where they need to be with respect to LIS.

Strategic Goal	Description	Strategic Objectives
Goal #1: Institute Uniform Information Sharing Policy and Governance	Enable the transformation of culture necessary for information sharing: policies, governance models, standards, personnel formation, and compliance mechanisms.	a) Develop a policy framework to increase information sharing across the Structure and with external partners and customers. b) Establish governance mechanisms to instill common practices for information classification, clearance processing, and policy and standards compliance. c) Reduce risks to civil liberty and privacy infractions from greater information sharing. d) Ensure policy implementation through institutionalized training programs and standards for information sharing policies and procedures. e) Resolve information sharing disputes.

Goal #2: Advance Universal Information Discovery and Retrieval	Advance information search, discovery, retrieval, dissemination, and pervasive connectivity through common metadata tagging.	a) Define common metadata tagging standards for information to achieve discovery, search, and retrieval objectives. b) Establish "universal discovery" processes, procedures, standards, and tools to support information transparency. c) Develop retrieval protocols to information repositories based on analytical focus, mission needs, and identity attributes. d) Integrate Open information networks at each possible level.
Goal #3: Establish a Common Trust Environment	Put in place uniform information identity attributes, management, information security standards, information access rules, auditing, and access control to promote common trust.	a) Define a uniform information structure and uniform attributes to enable information management, develop uniform standards and guidance for information management, and support decentralised, stakeholder-specific implementation. b) Establish information management standards for authentication, authorization, auditing, and cross-domain services. c) Develop information security policies to support logical and physical data protection efforts. d) Create a common classification guide for the Space Community. e) Establish a risk management approach that supports the common trust and information environment while still protecting sensitive information from disclosure.
Goal #4: Enhance Collaboration Across the Community	Develop the tools and incentives necessary at the institutional, leadership, and workforce levels to collaborate and share knowledge and expertise and information.	a) Develop information sharing communication programs to create awareness of a "responsibility to provide" culture. b) Create award and assessment programs to transform the culture from a "need-to-know" to a "responsibility to provide" mindset. c) Serve as an integration point for establishing a virtual collaboration environment to facilitate collaboration and information sharing among Community (e.g., analysts and collectors). d) Enable the Community stakeholders and partners to connect on a time-imperative basis to fulfil their mission requirements.

Section 3 - A case study

This section contains a case study intended to illustrate how States should share information in a manner that satisfies their legal obligations to register space objects and share information regarding space activity under the Outer Space Treaty and other instruments of space law.

3.1. The Scenario: Lunar Water Works SA

Lunar Water Works SA (LWW), a company incorporated in State A, is planning to undertake multiple lunar missions (i) to prospect for water ice on the south pole of the moon, (ii) to harvest the ice, and (iii) to process the ice into usable water, oxygen, and hydrogen. To power the operation, LWW will also operate the LWW Solar Energy Farm located at a Peak of Eternal Light on the rim of the Shackleton Crater.[1] The entirety of LWW's operations (including prospecting, harvesting, processing, and the solar farm) would take place within a square area measuring one (1) km by one (1) km.

3.2. How to Share Information About Safety Zones?

There are two primary methods of sharing information through the United Nations: the Registration Convention Register and the Article XI OST Index. It is recommended that all State Parties to the Outer Space Treaty always share information through submissions to the Article XI Index due to its better suitability to lunar missions. As a complement to that, all State Parties to the Registration Convention should also ensure that their space objects are duly registered as required under the Convention

Safety zones are intended to ensure the safety of operations and crews ~~astronauts~~ while also helping to avoid harmful interference by providing information about the location and nature of activities on the Moon. The dimensions of a safety zone are determined unilaterally by the responsible State upon consideration of the location and nature of the protected activity.

Safety zones can be viewed as “buffer zones” around the site where operations will take place. If this perspective is adopted, State A would share the dimensions of this “Zone of Operation” in which an actor will be conducting operations on the surface of the moon. Further, the submitting State should also provide the dimensions of one or more types of safety zones.

For this case study, three areas will be described (including two types of safety zones):

a) The Zone of Operation (ZoO)
The general area in which activities will be conducted.

b) The General Safety Zone (GSZ)
The area surrounding the ZoO in which other actors should operate in light of (1) their duty to exercise due regard and (2) the potential need of undertaking appropriate international consultations prior to entering or operating within the GSZ.

c) The Launching and Landing Safety Zone (LLSZ)
The area surrounding the ZoO within which other actors should launch or land a space vehicle in light of (1) their duty to exercise due care and (2) the potential need of undertaking appropriate international consultations prior to launching or landing within the LLSZ.

In determining the dimensions of the GSZ and the LLSZ, State A would take into account the particular nature of LWW’s operations including (i) LWW’s plan to prospect for and harvest ice throughout the ZoO and (ii) the operation of solar panels that can be harmed if covered by dust created by the launching or landing of a space vehicle.

The following paragraph provides a minimalistic example of the type of information that should be submitted to the Article XI Index regarding LLW’s mining operation. Note that this information includes not only coordinates and land measurements, but also describes (i) the particular nature of the protected activity and (ii) the reasons underlying the dimensions of the zones.

- *Zone of Operation (ZoO)*

The ZoO will occupy a square area measuring 1 km by 1 km.

- *The General Safety Zone (GSZ)*

The General Safety Zone extends two (2) kilometers beyond the borders of LWW’s operations. The outer borders of the GSZ form a square measuring 5 km x 5 km.

- *The Launching and Landing Safety Zone (LLSZ)*

A Launching and Landing Safety Zone (LLSZ) extends four (4) kilometers beyond the borders of LWW's operations. The outer borders of the GSZ form a square measuring 9 km x 9 km. This LLSZ is necessary to prevent potential harmful interference with the operation of LWW Solar Energy Farm due to the settling of dust on the panel faces or the accumulation of dust on the mechanical gears that allow the panels to be properly oriented.

Although different from the types of safety zones discussed above, State A might also conceivably use the Article XI Index to share information that would have the effect of protecting LWW's Solar Energy Farm from the risk of sunlight being blocked by new installations (such as a row of parked SpaceX Starships). To protect against such interference by providing notice, State A might consider providing the following information for inclusion in the Article XI Index:

The operation of the LWW Solar Energy Farm could be adversely affected by the construction of new installations which (whether individually or collectively) harmfully interfere with the efficient operation of the Farm's solar panels.

Although the Registration Convention only requires the registration of an object that has already been "launched" into space[5], Article XI of the OST allows for the sharing of information at any time. For maximum transparency, we recommend that information regarding space activities should be notified to the UNSG *prior to* the commencement of the activity. Such prospective submissions may help prevent potentially harmful interference between the forthcoming activity and other ongoing or future lunar activities. As the activity commences and evolves, State A should make supplemental submissions in order to add to and update the information in the original submission.

3.3. Potential Limitations due to Intellectual Property & National Security Concerns

LWW plans to use mining equipment of a certain type that will provide it with a significant competitive advantage. This mining equipment happens to be particularly vulnerable to lunar dust which harms the rotary action of the equipment. LWW should not be required to share such information in order to maintain its competitive advantage.

Having said that, even if LWW is not required to disclose information regarding resource location and the nature of its mining equipment, it may be in LWW's benefit to do so. For example, by explaining that its equipment is vulnerable to lunar dust, other operators will be placed on notice and will be obliged under international law to conduct their operations in the vicinity in a manner that pays due regard to the legitimate interest of LWW to protect its mining operations from potentially harmful interference caused by the creation of lunar dust.

Article XI OST provides that States "inform the Secretary-General of the nature, conduct, locations and results of [space] activities" only to the extent that sharing such information is "feasible and practicable." If State A prohibits the disclosure of sensitive technologies to foreign persons under its export-control laws and regulations (including disclosure by the State), the sharing of controlled data would not be "feasible" on the grounds that it would violate national legislation. Even if not in violation of a domestic law, the sharing of sensitive technologies might be neither feasible nor practicable due to national security concerns. For either reason, State A would be excused from sharing said technology with the Secretary-General.

As is true with controlled technology, Article XI does not require States (and by extension, their private operators) to share proprietary business information or intellectual property if disclosure is not "feasible and practicable." In other words, operators are excused from sharing information that would cause significant harm to a significant and legitimate business interest. Underpinning this concept is the need (and the right) of operators to maintain its financial viability and competitive advantages. For example, LWW would not be required to disclose proprietary information that would rob LWW of a key competitive advantage, such as knowledge of the precise location of rich ice resources, unless that would be required by legal obligations under either national or international law. Another protected type of information might be a description of proprietary confidential technology (whether or not the technology is protected by a patent or other intellectual property law) that LWW will use in its mining operations. The question here is (1) whether the information at issue is proprietary and confidential and (2) whether disclosure would cause significant harm to the operator's business interests.

Section 4 - Way Forward for the Development of LIS Datasets and Institutions

Information is only as powerful as are the means available for putting it into fruition. This is the reason why in SG1 we decided to complement our work on practical tools and case studies for lunar information sharing with actionable proposals on the development of datasets and institutions to respectively host and manage lunar information sharing.

4.1. Datasets

The importance of dedicated datasets for lunar information sharing stems from the many benefits produced by information when meaningfully organized. If properly arranged, raw data, information and knowledge on lunar activities might become a powerful tool of coordination and cooperation.

In accordance with Articles I and III OST, information sharing can be a powerful way to share the benefits of lunar activities with all humankind through international cooperation. To serve these purposes, we suggest the complementary use of governmental and non-governmental datasets, and to organize both of them around the key principles of openness and transparency.

- *Governmental Datasets*

Governmental datasets would be those developed and managed by either a national government or the UN Office for Outer Space Affairs (UNOOSA). These datasets would be fed with information officially collected by States (e.g. through their licensing processes) and then hosted in their national registries or internationally shared through diplomatic channels under Article XI OST, the Registration Convention or Resolution 1721(XVI) B. Among these channels, we recognize the potential of the “Index on Submissions by States under Article XI OST” to serve as the primary platform for hosting information about activities in the exploration and use of the Moon.

At present, concretely useful information required under Article XI OST (such as nature, location and duration of a given activity) are not *prima facie* visible in the Index. Further, the Index hosts all notifications and submissions ever sent by States under Article XI OST since 1967, which makes it difficult to use it for lunar coordination purposes. To address these issues and enhance the practical relevance of the Index, we suggest to create a sub-section dedicated to lunar activities and arrange it with a more *user-friendly* interface displaying information on actual *missions* rather than State’s notifications or *submissions*, as exemplified in the figure below.

1 Example of Lunar Index interface

Mission	**State(s)**	**Operator(s)**	**Status**	**Nature**	**Location**	**Duration**	**Additional information**
Artemis 1	USA	NASA	Planned (March 2022)	Technology demonstration	Circumlunar orbit	25 Earth days	[hyperlink to submission]

- *Non-Governmental Datasets*

By definition, non-governmental datasets would be all those set up by non-governmental entities. These platforms would be fed with information on lunar activities either discovered by their managers or submitted by external contributors. Non-governmental databases would allow all interested entities to participate in lunar information sharing and could ensure the inclusion of other types of information that would not be normally hosted in formal databases (like detailed technical parameters or constantly updated data). To serve these purposes, we recommend the development of a global, neutral and interactive platform publicly and freely available for consultation as well as open to contributions from all stakeholders based on open-source licensing. Any non-governmental entity interested in setting up such a dataset is welcome to contact SG1 to explore opportunities for cooperation and synergies.

- *Coordination Mechanisms*

The practical usefulness of lunar information will critically depend on the ability to align data provided by different sources in a consistent manner. Thus, in addition to setting up various datasets for hosting lunar information, we consider it is important to ensure institutional coordination among them with a view to improving the quality and utility of the lunar information stored therein.

According to Article XI OST, Member States have an obligation to share information about their lunar activities (as a category of "activities in outer space") with the UNSG, the public and the international scientific community, which logically calls upon these three receivers to coordinate among themselves to better use of the shared information. Either voluntarily or preferably through an institution, regular and interactive engagement between different lunar datasets should be promoted as a critical means for lunar sustainability.

4.2. Institutions

For the above reasons, we consider the development of templates and protocols for lunar information sharing, followed by the organization of shared information in dedicated lunar databases, to be critical but also preliminary steps. As more and more actors engage in the exploration and use of the Moon, the likelihood of potential overlaps across lunar activities - for good or for worse - will grow substantially. Whether these overlaps will end up in conflict depends on the availability of recognized, effective structures and procedures to peacefully address them. In the lack of international lunar governance, the institutionalized opportunity for consulting about lunar activities is at least as important as the information shared about them.

a) *Institutional suggestions for "appropriate international consultations"*

Under Article IX OST, a State with reasons to believe that its space activities might harmfully interfere with those of other States shall undertake "appropriate international consultations". This broad expression has been chosen by the OST drafters to allow for the development of diversified solutions which can be tailored to specific space activities. The establishment of dedicated bodies for reviewing lunar information would provide an effective tool to conduct the "appropriate international consultations" required by the OST.

The question then becomes: *which institution?* In principle, the variety of entities operating within the space community offers many potentially good answers to this question. For example, a dedicated lunar consulting institution could take the form of an inter-agencies consultation body, following the example of the "International Space Exploration Coordination Group" (ISECG). Such an entity could also be developed as an expert-based multi-stakeholder platform, similar to what has happened with GEGSLA. Finally, it could be set up as a dedicated working group within UNCOPUOS, like the Legal Subcommittee has done in 2021 for space resources. While all these solutions have their merits and demerits, the truth is that none of the existing examples would prove to be an optimal solution. An inter-agency group would leave out private operators, while vice versa industry groups would do the same with space agencies. Significantly, both would lack tools to incorporate civil society's feedback and give consideration to interests from the general public. A multi-stakeholder platform like GEGSLA would lack the political mandate to take any decision, whereas a UNCOPUOS working group would have difficulties to act in a timely manner.

One way to develop an optimal solution would be setting up *all these entities* to each coordinate a specific segment of the lunar community. This polycentric approach would have the merit of bringing the development of potential solutions closer to their intended beneficiaries. At the same time, entrusting multiple entities with the same consultative function poses a serious risk of divergence. This risk could be neutralized by a formal distribution of competences among these entities coupled with the development of a shared forum for mutual exchanges of views among their representatives. However, while these mechanisms would contribute to minimum alignment, they would also add further layers of complexity impacting efficient and effective functioning.

b) *Summary of potential options for LIS Institutions*

a) Interagency Lunar Coordination Committee

Rationale: build upon the successful experience of the IADC, IDCC and ISECG
Pros: technically focused, legitimacy as expert body established by States
Cons: unfit to discuss legal and policy issues; excludes industry and private actors
Solution: expand membership to fill expertise and stakeholder's gaps

b) Lunar Coordination Forum

Rationale: spinoff combining GEGSLA, Registration Project, Moon Dialogues
Pros: inclusive and effective multistakeholder platform
Cons: lack of political mandate; unfit to consult/conciliate at high level
Solution: reconnect with decision-makers through appropriate institutional procedures

c) Lunar Coordination Mechanisms within COPUOS

Rationale: capitalize COPUOS' potential as the only Committee of UN General Assembly dealing with peaceful use of outer space and its universal representativeness
Pros: multilateral diplomatic body merging legal & technical expertise
Cons: unfit to respond in a timely manner; excludes private actors
Solution: hold single agenda item discussions at the Committee in preparation to the future establishment of a working group leveraging intersessional work and stakeholders' contributions.

d) Polycentric Governance

Rationale: one entity cannot deal with all the problems
Pros: polycentric approach with each institution playing its strengths
Cons: fragmented approach, risk of divergent solutions
Solution: develop formal allocation of competences and links among bodies.

Section 5 - Conclusion

The ideas expressed in this document are meant to provide constructive suggestions that could be rapidly implemented in relatively uncontroversial ways. They build upon existing international space law and are driven by the goal of supporting its faithful implementation in the context of lunar activities. We hope our considerations could trigger a global conversation on the consistent development of best practices for sharing information about lunar activities. With as many as 106 lunar missions planned for the present decade, we urge the international community to conduct said conversations in good faith and to approach them with a practical, not ideological, mindset.

PART B: Safe Operations and Lunar Environmental Protection

Table of Content

Section 1: Safety Zones

Executive Summary

This memorandum recommends the establishment and public notice of Safety Zones when conducting lunar activity. The following bullet points provide a brief summary of the recommendations:

a) When conducting lunar activity, the authorizing State should provide notice to the UN Secretary-General, to be publicly disseminated, of a Safety Zone surrounding the site of such activity with the primary goals of (i) ensuring safety, (ii) avoiding harmful interference, (iii) protecting the legitimate interests and rights of other States.

b) Notice of a Safety Zone should provide clear geographic dimensions determined in accordance with the principles of necessity, equilibrium, optimization, and coordination.

c) Notice of a Safety Zone should include sufficient information regarding the nature of the activity to enable other operators in the vicinity (i) to maintain safety, (ii) to operate in compliance with their duty of due regard, and (iii) to conduct appropriate consultation under Article IX of the Outer Space Treaty to avoid harmful interference.

d) Safety Zones are purely informational, have no inherent legal effect, and are subject to the principle of free access under international law.

e) Safety Zones should be updated if activities change and, being temporary in nature, should be terminated when activity is concluded.

a. Introduction

Beginning in 2022, a steady procession of missions to the surface of the Moon will commence, undertaken by multiple space agencies as well as private operators. These missions, which will include both crewed and robotic missions, will involve a variety of activities including, among other things, scientific exploration, the establishment of human habitats, solar energy farming, and resource extraction and processing. Considering multiple missions being undertaken in similar locations (such as the polar regions), there is a risk of harmful interference and potential legal and political disputes among operators. In order to avoid or solve such issues, the establishment of so-called "safety zones"[1] have been proposed in various fora.

b. Purpose of Safety Zones

The purpose of safety zones is to provide notice to others of the location and nature of an operator's activities in order to:

- promote the safety of lunar activities;
- avoid harmful interference among lunar operations; and
- prevent legal and political disputes among concerned parties.

[1] The international community could consider whether a term other than "safety zone" would be more appropriate. One alternative would be "notification and coordination zone".

c. Definitions

- Safety Zone: an area with clear geographic parameters publicly noticed surrounding the site of lunar activities established in order to ensure safety, avoid harmful interference among lunar activities, and prevent disputes arising from legitimate rights and interests.[2]
- Authorizing State: the State which authorizes and supervises lunar activity and establishes the related Safety Zone.

d. Objective of International Framework of Safety Zones

Any international framework regarding Safety Zones should have the following as its objectives:

- The recognition and protection of legitimate rights, interests of all relevant parties;
- The resolution of existing or potential disputes; and
- The fair and efficient use of lunar resources for the benefit of all humankind.

e. Rationale for the Establishment of International Framework of Safety Zones

Four principles should be considered to formulate the international framework or mechanisms of safety zones, which are: necessity, equilibrium, optimization and coordination.

- The principle of necessity means that the Authorizing State should provide explanations in support of the scope, duration, and nature of this zone, prior to its establishment.
- The principle of equilibrium is to balance between the right to be free from harmful interference and the freedom to access, explore, and use of all areas, no matter whether the actors concerned are the first comer, late comer, parties in a cooperative lunar project, or any other party.
- The principle of optimization is a furtherance of the principle of equilibrium. Equilibrium does not necessarily mean egalitarianism, but is guided by the rationale of efficiency, aiming at leveraging the full use of any Safety Zones in favor of all the stakeholders, as well as all humankind.
- The principle of coordination should be the core value of an international framework regarding safety zones. The principle of coordination should provide guidance as to the formulation of certain mechanisms under the international framework regarding, for instance, information sharing, notification, consultation, and other tools and processes of coordination.

Moreover, any international framework regarding Safety Zones should comply in all aspects with international space law, including but not limited to the non-appropriation principle under Article II of the Outer Space Treaty.

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[2] NASA's Artemis Accords require signatories: *". . . to provide notification of their activities and commit to coordinating with any relevant actor to avoid harmful interference. The area wherein this notification and coordination will be implemented to avoid harmful interference is referred to as a 'safety zone'".*

f. The Legal Effect of Safety Zones

Safety Zones are purely informational and have no inherent legal effect. Safety Zones and their establishment and operation are not tools for national or private appropriation of such zones. They are not exclusion zones and do not, in and of themselves, grant the operator jurisdiction and control of the area, nor entail automatic responsibility for harm caused within the area under *lex lata*. All parties are free to travel and operate within a Safety Zone with the understanding that they should comply with their legal obligations, such as the duties (i) to operate with due regard and (ii) to consult with potentially affected parties if there is a possibility of causing harmful interference with activities of the affected parties. The publication of safety zones is conducive to assisting all parties to fulfill these duties.

g. The Establishment and Notification of Safety Zones

The Authorizing State should determine the dimensions of a safety zone after consulting and coordinating with those States whose lunar activities or other legitimate interests would be affected by the establishment of such a Safety Zone.

The dimensions of a safety zone should be determined in light of:

- the safety of all existing and known future parties operating on the Moon that may be affected by the planned zone;
- the potential of harmful interference with other existing and planned operations;
- the operational necessity of the safety zone;t
- he interests of other existing and known future parties with the goal of reaching an equilibrium that balances relevant interests, economic efficiency, and optimization of lunar activities.[3]

When providing notice of Safety Zones, the following information should be submitted:

- the precise location of related equipment and activities within the safety zone;[4]
- the dimensions of the safety zone;
- a description of the nature of the lunar activity in sufficient detail to alert others about potential interference or safety issues;
- the identity of the operator in control of the related equipment and activities;
- the extent of a human presence within the safety zone;
- the duration of the activity and presence of equipment; and
- the rationale for the dimensions of the safety zone.

Notice of Safety Zones should be submitted to the Secretary-General as soon as practicable and in no event later than the first delivery of related equipment or humans to the area. Information contained in a notification should be updated immediately upon (and when possible, in advance of) any changes to the information. When the activity has ended, the notification should be updated to reflect such termination.[5] (Non-governmental entities which are carrying on or plan to conduct

[3] Among the more important concepts to balance is the right to be free from harmful interference with the right to free access.

[4] All locations should be stated in accordance with the appropriate Geographic Information System.

[5] If equipment is left *in situ* following the termination of the activity, the updated notice should indicate this.

lunar activities with a legitimate need to establish a safety zone should provide the necessary information to the State authorizing such activity, to be submitted in turn to the Secretary-General by this State.)

All notices of Safety Zones should be broadly publicized and made publicly available and easily accessible at no cost. The precise process and method employed by the Secretary-General to publicize Safety Zone notifications is yet to be determined. One possibility would be to include the information on one of the two public registries maintained by the UN (which includes the index maintained pursuant to the Registration Convention and the index maintained pursuant to Article XI of the Outer Space Treaty). The Responsible State would provide information regarding the Safety Zone for inclusion in these registries by diplomatic note before registering the related space objects and activity.

h. Coordination and Consultation After the Establishment of a Safety Zone

Following the establishment and the notification of a Safety Zone, if potentially harmful interference with the activity of the Authorizing State may result from another operator's plans to land, enter, transit, or conduct activity within the Safety Zone, consultations must be requested. Even in the absence of potential harm, prior notice and coordination with the Authorizing State should be strongly encouraged.

Appendix A: Section 11 of the Artemis Accords

SECTION 11 – DECONFLICTION OF SPACE ACTIVITIES

1. *The Signatories acknowledge and reaffirm their commitment to the Outer Space Treaty, including those provisions relating to due regard and harmful interference.*
2. *The Signatories affirm that the exploration and use of outer space should be conducted with due consideration to the United Nations Guidelines for the Long-term Sustainability of Outer Space Activities adopted by the COPUOS in 2019, with appropriate changes to reflect the nature of operations beyond low-Earth orbit.*
3. *Consistent with Article IX of the Outer Space Treaty, a Signatory authorizing an activity under these Accords commits to respect the principle of due regard. A Signatory to these Accords with reason to believe that it may suffer, or has suffered, harmful interference, may request consultations with a Signatory or any other Party to the Outer Space Treaty authorizing the activity.*
4. *The Signatories commit to seek to refrain from any intentional actions that may create harmful interference with each other's use of outer space in their activities under these Accords.*
5. *The Signatories commit to provide each other with necessary information regarding the location and nature of space-based activities under these Accords if a Signatory has reason to believe that the other Signatories' activities may result in harmful interference with or pose a safety hazard to its space-based activities.*
6. *The Signatories intend to use their experience under the Accords to contribute to multilateral efforts to further develop international practices, criteria, and rules applicable to the definition and determination of safety zones and harmful interference.*
7. *In order to implement their obligations under the Outer Space Treaty, the Signatories intend to provide notification of their activities and commit to coordinating with any relevant actor to avoid harmful interference. The area wherein this notification and coordination will be implemented to avoid harmful interference is referred to as a 'safety zone'. A safety zone should be the area in which nominal operations of a relevant activity or an anomalous event could reasonably cause harmful interference. The Signatories intend to observe the following principles related to safety zones:*

    (a) The size and scope of the safety zone, as well as the notice and coordination, should reflect the nature of the operations being conducted and the environment that such operations are conducted in;

    (b) The size and scope of the safety zone should be determined in a reasonable manner leveraging commonly accepted scientific and engineering principles;

    (c) The nature and existence of safety zones is expected to change over time reflecting the status of the relevant operation. If the nature of an operation changes, the operating Signatory should alter the size and scope of the corresponding safety zone as appropriate. Safety zones will ultimately be temporary, ending when the relevant operation ceases; and

(d) The Signatories should promptly notify each other as well as the Secretary-General of the United Nations of the establishment, alteration, or end of any safety zone, consistent with Article XI of the Outer Space Treaty.

- *The Signatory maintaining a safety zone commits, upon request, to provide any Signatory with the basis for the area in accordance with the national rules and regulations applicable to each Signatory.*
- *The Signatory establishing, maintaining, or ending a safety zone should do so in a manner that protects public and private personnel, equipment, and operations from harmful interference. The Signatories should, as appropriate, make relevant information regarding such safety zones, including the extent and general nature of operations taking place within them, available to the public as soon as practicable and feasible, while taking into account appropriate protections for proprietary and export-controlled information.*
- *The Signatories commit to respect reasonable safety zones to avoid harmful interference with operations under these Accords, including by providing prior notification to and coordinating with each other before conducting operations in a safety zone established pursuant to these Accords.*
- *The Signatories commit to use safety zones, which will be expected to change, evolve, or end based on the status of the specific activity, in a manner that encourages scientific discovery and technology demonstration, as well as the safe and efficient extraction and utilization of space resources in support of sustainable space exploration and other operations. The Signatories commit to respect the principle of free access to all areas of celestial bodies and all other provisions of the Outer Space Treaty in their use of safety zones. The Signatories further commit to adjust their usage of safety zones over time based on mutual experiences and consultations with each other and the international community.*

Appendix B: Hague Working Group Building Blocks on Safety Zones

11.3. Taking into account the principle of non-appropriation under Article II OST, the international framework should permit States and international organizations responsible for space resource activities to establish a safety zone, or other area- based safety measure, around an area identified for a space resource activity as necessary to assure safety and to avoid any harmful interference with that space resource activity. Such safety measures shall not impede the free access, in accordance with international law, to any area of outer space by personnel, vehicles and equipment of another operator. In accordance with the area-based safety measure, a State or international organization may restrict access for a limited period of time, provided that timely public notice has been given setting out the reasons for such restriction.

11.4. The international framework should provide that appropriate international consultations are undertaken in case of possible overlap of safety zones or conflicts involving the freedom of access recognized by international law.

Section 2: Lunar Heritage

a) Definitions

A *lunar cultural heritage site* is any place with human material culture on the Moon or that is associated with intangible practices, representations, expressions, knowledge, or skills, that has historic, social, aesthetic, spiritual, or scientific significance for present and future generations.
A l*unar natural heritage site* is any place, geological or landscape formation that has historic, social, aesthetic, spiritual, or scientific significance for present and future generations.

Lunar cultural heritage sites may be located on the surface, subsurface, or in orbit. The extent of a lunar surface cultural heritage site may include all physical objects, marks, or traces in the regolith that are associated with robotic and human activities carried out in that location or using the equipment placed at that location (e.g., rover tracks, sample pits, rocket plumes, chemical alterations). It also may include the views and landscapes experienced by crewed missions or robotic cameras, which correspond to images disseminated on Earth. A site could be defined as all traces left by the activities of one distinct mission.

A *lunar cultural landscape* is the combined work of cultural and natural processes. Cultural landscapes are 'illustrative of the evolution of human society and settlement over time, under the influence of the physical constraints and/or opportunities presented by their natural environment and of successive social, economic, and cultural forces, both external and internal' (Operational Guidelines 2019: 20).

As defined by the Operational Guidelines to the World Heritage Convention (2019:83), cultural landscapes fall into three types:

- Intentionally designed
- Organically evolved, which can be relict (activities have discontinued in the landscape) or continuing
- Associative, which may have powerful religious, artistic, or cultural associations of the natural element rather than material cultural evidence, which may be insignificant or even absent.

A cultural landscape may have elements of all three. All current lunar sites could be defined as organically evolved cultural landscapes. The near face of the Moon is an associative cultural landscape. Craters, maria, geological features, and albedo combine to create the landscape observed by human, ancestral human, and non-human observers. The process of naming also creates associative landscapes on the Moon. This is enhanced when features can be seen by people on Earth with the naked eye or with telescopes. For example, Shackleton crater has cultural associations. Impacts to the visible face of the Moon through lunar activities have the potential to alter the values of this landscape.

A *lunar heritage precinct* contains more than one cultural heritage site and may be associated with natural heritage values. Examples include Surveyor 3 and Apollo 12.

Cultural heritage includes tangible and intangible components.

Section 3: Debris Mitigation and Environmental Sustainability

a) Introduction

In 2015, under the General Assembly Resolution A/RES/70/1 "Transforming our world: the 2030 Agenda for Sustainable Development" the 17 Sustainable Development Goals (SDGs) and 169 targets were adopted to stimulate action till 2030 in areas of critical importance for humanity and the planet. One of the most important directions in that regard is a necessity "to protect the planet from degradation, including through sustainable consumption and production, sustainably managing its natural resources and taking urgent action on climate change, so that it can support the needs of the present and future generations." In the XXI century, environmental problems and concerns appear even more important. At the same time, they "are often addressed only after their effects are seen, such that damage is minimized rather than reversed or prevented.[6]" To protect and to save the Earth's environment, it is required to ensure environmental sustainability "acting in a way that ensures future generations have the natural resources available to live an equal, if not better, way of life as current generations"[7] as well as "stabilizing the currently disruptive relationship between Earth's two most complex systems: human culture and the living world."[8] However, environmental sustainability issues nowadays extend beyond the Earth.

According to the US Department of Defence's global Space Surveillance Network (SSN) more than 15,000 pieces of space debris larger than 10 cm have been tracked. It is also estimated that there are around 200,000 pieces sized between 1 and 10 cm 0.4 and 4 inches, and millions of pieces smaller than 1 cm. Based on the realization that humanity uses the results and benefits of space activities, space debris prevention and mitigation is considered to be one of the targets in ensuring environmental sustainability in a broader sense, taking into account the exploration of the Moon and its orbits in the near-term perspective.

However, as the lunar environment differs from the Earth's environment, States and lunar stakeholders should use appropriate methods and approaches tailored to ensure lunar sustainability. The lunar environment is characterized by a lack of a significant atmosphere, which means that there is no protection from solar radiation or micro-meteorites. Also, the Moon does not have a magnetic field and its surface is directly affected by the solar wind and galactic cosmic rays. In addition, the lunar surface is covered by fine dust that can be unintentionally moved by rocket plumes. Lunar dust is harmful to both astronauts and robots. Orbits around the Moon will increasingly be sought-after as lunar stakeholders deploy assets in orbit or enter orbit on their way to the surface. All these conditions will be challenging to humans and spaceflight operations. The gravity of the Moon is 6 times weaker than the gravity of the Earth. The surface of the Moon is seismically active; moonquakes come in strengths up to 5.5 on the Richter scale.

Bearing in mind that it has been a common understanding that the current space debris environment has already posed a risk to spacecraft in Earth orbit, the following guidelines are aimed at curtailing the generation of potentially harmful space debris in the near term and limiting their generation

[6] Early warning on emerging issues URL: https://www.unep.org/explore-topics/environment-under-review/what-we-do/early-warning-emerging-issues

[7] United Nations Environment Programme. "Sustainability." URL: https://www.unep.org/about-un-environment/sustainability

[8] Evans M. What Is Environmental Sustainability? Definition & Examples of Environmental Sustainability URL: https://www.thebalancesmb.com/what-is-sustainability-3157876#citation-1 (Updated on July 07, 2020).

over the longer term during lunar activities on and around the Moon, its orbits, [as well as for missions traveling to and returning from the Moon][9] and ensuring the environmental sustainability of the Moon and its orbits.

b) Definitions

- Debris for the purposes of the lunar orbit and lunar surface environment is defined as:
  - Human-made objects including fragments and elements thereof, that are non-functional, or
  - Naturally occurring lunar rock and regolith that are unintentionally moved by spacecraft or human activity that pose substantial risk of harm to others. [10]
- Debris Mitigation is defined as: the enactment of practices and policies that prevent the proliferation of human-made debris including fragments and elements thereof in lunar orbit or on the lunar surface; or the prevention of naturally occurring lunar rock or regolith from being moved and striking astronauts or structures, facilities, equipment, vehicles, or spacecraft on the lunar surface.
- Environmental Sustainability is defined as: the ability to maintain the conduct of space activities on and around the Moon indefinitely into the future in a manner that realizes the objectives of equitable access to the benefits of the exploration and use of outer space for peaceful purposes, in order to meet the needs of the present generations while preserving the outer space environment for future generations.[11] [12]
- Launching State is defined as: a State which launches or procures the launching of a space object, or a State from whose territory or facility a space object is launched.[13]
- Harmful interference in the lunar environment is defined as: undertaking an activity which prevents other actors from carrying out their legitimate lunar activities or gaining access to an area; contaminates or depletes a resource being utilized by another actor or presents risks to the safety of lunar activities.
- Harmful Contamination of a lunar environment or lunar orbits is defined as the deliberate or unintentional changing of that environment through the introduction of extra-environmental materials or otherwise, so as to cause harmful interference with other actors carrying out legitimate lunar activities such as science, exploration, or commerce; or to damage sites of scientific or cultural importance.
- Safety Zone: an area with clear geographic parameters publicly noticed surrounding lunar activities established in order to ensure safety, avoid harmful interference among lunar activities, protect heritage sites, and prevent conflicts arising from legitimate rights and interests.
- Sustainable is defined as capable of being continued after an activity has occurred in the environment.
- In the definition of environmental sustainability can be integrated the notion of depletion or degradation of natural resources, that is relevant to in-situ resources utilization. This

[9] From the UN COPUOS Debris Mitigation Guidelines 2007

[10] Adapted from the definition in the "IADC Space Debris Mitigation Guidelines" in March 2020;

[11] Guidelines for the Long-term Sustainability of Outer Space Activities 2019

[12] UN Doc. A/74/20. Annex II. Guidelines for the Long-term Sustainability of Outer Space Activities of the Committee on the Peaceful Uses of Outer Space. P. 50.

[13] LIAB + REG

allows for long-term environmental quality for future generations to be able to live an equal, if not better, way of life as current generations.

- Lunar sustainability is defined as responsible interaction with the lunar environment (including lunar orbits) to avoid the degradation of lunar resources; allow for long-term environmental presence and utilization of the Moon; and maintain the conduct of lunar activities indefinitely into the future in a manner that realizes the objectives of equitable access to the benefits of the exploration and use of the Moon for peaceful purposes, [in order to meet the needs of the present generations while preserving the Moon for future generations].

c) Background

The intent behind debris mitigation in lunar orbits and the lunar surface is to ensure these environments can be accessed and utilized by current and future generations of public and private lunar stakeholders. Debris mitigation in this context is the practice of:

a) Preventing break-ups in lunar orbits
b) Passivating of space crafts that have reached the end of their mission to eliminate stored energy on a spacecraft
c) Preventing the unintentional break up of assets on the lunar surface
d) [Preventing human-made objects (whether or not they can be contacted, including the final stages of launch vehicles) from hitting the lunar surface without coordination].

e) International norms

In the context of promoting debris mitigation and ensuring environmental sustainability on the lunar surface and around the Moon a number of international legal norms and recommendations exist in the following documents:

1. The Outer Space Treaty 1967
2. The Registration Convention 1975
3. The Moon Agreement 1979, however it is recognized that so far only 18 signatories have ratified the Agreement.
4. The Treaty Banning Nuclear Weapons Tests in the Atmosphere, in Outer Space and Under Water of 5 August 1963
5. The Guidelines for the Long-Term Sustainability of Space Activities 2019 (A/74/20, para 163 and Annex II)
6. Safety Framework for Nuclear Power Source Applications in Outer Space 2009 (A/AC.105/934, 2009)
7. The Constitution, Convention, and the Radio Regulations of the International Telecommunication Union (ITU)
8. The Artemis Accords 2020
9. The Hague International Space Resources Governance Working Group Building Blocks for the Development of an International Framework 2019
10. Documents of COSPAR (recommendations, requirements) relating to the protection of the Moon, its surface, and orbits

International instruments relating to space debris:

11. Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space 2007 (A/62/20, Annex and General Assembly Resolution 62/217 of 22 December 2007)
12. IADC Space Debris Mitigation Guidelines
13. International Telecommunications Union (ITU): Recommendation ITU-R S.1003.2
14. European Code of Conduct for Space Debris Mitigation
15. ISO Standards
16. A Compendium of Space Debris Mitigation Standards adopted by States and international organizations also exists and is being updated on a regular basis by the UN COPUOS.

f) Debris Mitigation: Recommendations and Technical Guidelines

- *Pre-launch Phase*
- Space systems constructed for lunar activities should be designed to avoid the release of nontrivial debris during normal operations [within lunar orbits or on the lunar surface]. If this is not feasible, the effect of any release of debris in lunar orbits or on the lunar surface should be minimized to the greatest extent practicable.
- Design and planning for spacecraft operations that will transit or operate in lunar orbit planning should include consideration for coordination, consultation, and information sharing.

- *Operational Phase*

a) In the interest of transparency and the prevention of break-ups during operational phases:

   a) Lunar stakeholders that operate assets in lunar orbits or on the lunar surface should be encouraged to voluntarily register the position of their assets with the launching State in which they originate.

   b) Launching States should be encouraged to publicly share position information of assets in lunar orbits as well as on or below the lunar surface.[14]

a) Recognizing that an increased risk of collision could pose a threat to space operations in lunar orbits or the lunar surface, the intentional destruction of non-functional space objects, assets, or other harmful activities that generate long-lived debris in lunar orbits or on the lunar surface should be avoided. When intentional break-ups are necessary, they should be conducted bearing in mind physical characteristics of the low Moon orbits which are usually not a circular orbit, because it is unstable.

[14] This could be modeled after the Registration Convention (1976). As stated by UNOOSA, "States and international intergovernmental organizations that agree to abide by the Convention are required to establish their own national registries and provide information on their space objects to the Secretary-General for inclusion in the United Nations Register. Responsibility for maintenance of the Register was delegated by the Secretary-General to the United Nations Office for Outer Space Affairs. As required under the treaty, UNOOSA publicly disseminates the information provided as United Nations documents, which are available through its website and through the United Nations Official Document System." This system could be replicated but on a voluntary basis for the Moon, with information submitted by launching states.

b) In order to limit the risk to other spacecraft from accidental break-ups and debris interference, all assets are advised to avoid touching down on the lunar surface within at least a 2-kilometer radius of other assets already on the lunar surface. Spacecraft should avoid touching down within a larger radius if they are likely to create harmful interference with other assets beyond a 2-km radius.[15] A 2-kilometer radius is a safety requirement to prevent landing spacecraft from inducing dust interference on surface assets in the area. With the lunar horizon approximately 1.8-km away from a given asset on the surface, this safety radius avoids dust interference from landing spacecraft. To this end, the specific measures and solutions are to be confirmed among the relevant stakeholders by coordination.

c) Certain safety zones should be established in the places of the common interest of lunar stakeholders [such as the Lunar South pole].

- *Post-Operational Phase*

a) In order to limit the risk to other spacecraft from accidental break-ups, all on-board sources of stored energy should be depleted or made safe when they are no longer required for mission operations or post-mission disposal in lunar orbits or the lunar surface.[16]

b) Non-functional space objects and assets that have reached the end of their operation in lunar orbits should take measures to avoid collision with assets on or below the lunar surface.

c) All missions on deorbiting of space objects should be conducted in a controlled manner, for doing it is recommended to establish a specialized deorbit zone.

d) If a space object is planned to be deorbited to the lunar surface, States and lunar stakeholders are recommended to consider using a dedicated debris disposal zone(s) if possible. Such an impact zone would support the establishment of lunar recycling service activities due to the higher concentration of debris material in the same place. The zone is recommended to be close to the region with lunar activities to allow a recycling process (like the raw materials) without jeopardizing lunar sustainability and lunar activities.

e) To ensure the sustainability of the Moon, States are recommended to hold a national registry of space debris and to promote the creation of the universal registry for space debris, which can be based on the UNOOSA platform.

f) In data exchange on space debris, it is recommended to use various forms of databases such as: involving sensors, servers, network, data AI/ML, blockchain or DLT integration, etc.

g) Environmental Sustainability: Recommendations and Technical Guidelines

[15] See: The implication of dust for Resource Contention and Lunar Policy. May 7, 2020. https://swfound.org/media/206980/moon-dialogs-research-salon-2-_-may-7-phil-metzger.pdf

[16] Recommendations 3, 4, and 5 are written in alignment with guidelines from the "Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space" in 2007.

a) Principles of Environmental Sustainability

Recognizing that the Moon, as a natural satellite of the Earth, has an important role to play in the exploration of outer space and bearing in mind the benefits that may be derived from the utilization of the natural resources of the Moon, States and lunar stakeholders should abide by the following principles of environmental and lunar sustainability:

- To prevent environmental harm to the Moon including its orbits, States and lunar stakeholders should follow the precautionary principle, which requires acting carefully and with foresight while conducting activities on or below the lunar surface or in lunar orbits to avoid negative consequences for the lunar environment. This principle should be followed in a manner that is based on scientific evidence.
- In order to prevent risks to environmental sustainability of the Moon, including the potential threat of organic and biological contamination of permanently shadowed regions (PSRs), States and lunar stakeholders should comply with due diligence obligations, including the observation of the principle of prevention[17] and the principle of good faith[18], as well as the Planetary Protection Policy adopted by the COSPAR.
- States should pursue studies of the Moon and conduct exploration of it in a manner that avoids its harmful contamination and, where necessary, shall adopt [appropriate] measures for this purpose.
- In order to prevent risks from future lunar activities, States should request that lunar stakeholders use voluntary environmental assessment tools before the start of such activities. [To promote the universal environmental assessment (hereinafter EA), it is suggested to create the "Space Environmental Commission" under UNOOSA's umbrella, which will be open for all States and lunar stakeholders and will be based on open tools and information sharing. Functions of such a body could include approval and overseeing mining projects, or charging fees to private companies, which would benefit the international community].
    1) Environmental Assessment and the strong consolidation of risk prevention should be considered due diligence.
    2) To maintain consistency, EA considers impact of every phase of the future lunar activity/mission (design, test, launch, operation, decommission, etc.) on the Moon and relevant space environment and includes an environmental

[17] A 'principle of general international law' is that no state has the right to use or permit the use of its territory in such a manner as to cause injury by fumes in or to the territory of another or the properties or persons therein, when the case is of serious consequence and the injury is established by clear and convincing evidence.

[18] Supplements due diligence obligations and deploys a constitutional quality in international law, persuading states to take measures and realise a regulatory aim.

risk assessment,[19] an environmental impact assessment report,[20] and environmental impact assessment.[21]

3) It is recommended to apply different forms of Environmental Impact Assessment, which can be used by States and future lunar stakeholders (see Annex 1 “Moon environmental assessment strategy” and Annex 2 “Environmental Impact Assessment. Notice for Operators”).

- If a lunar activity or experiment planned by a State or its lunar stakeholders on or below the lunar surface or in lunar orbits could cause potentially harmful contamination, it is recommended to States to arrange for remediation or mitigation as appropriate and provide proper notification of those activities.
- If a lunar activity or experiment planned by a State or its lunar stakeholders on or below the lunar surface or in lunar orbits could cause potentially harmful contamination, a [launching] State shall undertake [appropriate] international consultations before proceeding with any such activity or experiment.
- If a State or its lunar stakeholders have reason to believe that a lunar activity or experiment planned by another State or its lunar stakeholders on the lunar surface or in lunar orbits may cause potentially harmful contamination, a [launching] State, or its lunar stakeholders [through nationally and internationally recognized mechanisms] may request consultation concerning the activity or experiment.
- States shall conduct authorization and continuing supervision under the activities of its lunar stakeholders to avoid any harmful contamination of the Moon and its orbits. [To ensure monitoring of any harmful impacts to the Moon and lunar orbits resulting from lunar activities, it is suggested to create a universal mechanism of monitoring on the base of the UN OOSA].
- If a harmful impact resulting from a lunar activity occurs, or is reasonably expected to occur, the State(s) and/or lunar stakeholder(s) should implement measures to address the harm by adjusting or terminating the activity.

b) Lunar Planetary Protection

Recognizing that lunar planetary protection is an essential element of the environmental sustainability of the Moon, States and lunar stakeholders should be committed to transparency relative to the following lunar planetary protection requirements and mitigation methods [considering Principle 21 of the Declaration of the United Nations Conference on the Human Environment of 16 June 1972, and Principle 2 of the 1992 Rio Declaration on Environment and Development]:

1. In exploring and using the Moon and lunar orbits, States and their lunar stakeholders should take measures to prevent the disruption of the existing balance

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[19] Identifies potential environmental hazards caused by a business and determines its likelihood or probability to negatively affect various aspects of the environment such as living organisms, natural habitats, and ecosystems

[20] A document which is completed when it is decided that the project doesn't require an environmental impact statement

[21] It is used to identify the environmental and social impacts of a proposed project prior to decision-making in order to predict environmental impacts at an early stage in project planning and design

of its environment, whether by introducing adverse changes in that environment, by its harmful contamination through the introduction of extra-environmental matter or otherwise.[22]

2. Any space experiment conducted on or below the surface of the Moon or in lunar orbits should be evaluated to assess any substantive potential harm, in order to protect the Moon and outer space from biological, chemical and radiation contamination that represent serious environmental threats.
3. Possible sources of contamination of the Moon include but are not limited to, the release of chemical markers, radioactivity resulting from nuclear power sources, generation of gasses in connection with soft landings, introduction of terrestrial microorganisms, lunar dust dissemination, other non-nuclear explosions, and the inadvertent transport of living or other matter from the Earth to the Moon.[23]
4. In order to avoid adverse changes in the Moon's environment caused by introducing extraterrestrial matter from the Earth, and to protect its biological integrity for scientific study, States and their lunar stakeholders should classify any lunar activities as low or high risk. In doing so, it is recommended to take into account but not be limited to the Categories II (a) and II (b) of Planetary Protection Policy adopted by the COSPAR as relevant.[24]
5. States Parties should inform the UN Secretary-General of the measures being adopted by them and shall to the maximum extent feasible, notify the UN Secretary-General in advance of all placements of radioactive materials on the Moon and of the purposes of such placements.[25]
6. In order to prevent risks and protect the environmental sustainability of the Moon, States can leverage safety zones which include both notification and coordination obligations.
7. Activities by States and their lunar stakeholders in lunar orbits or on or below the lunar surface should be conducted in a manner that does not harm sites or artifacts that have cultural or scientific significance may jointly establish safety zones for the areas on the lunar surface or lunar orbits which have significant scientific or cultural significance. If such harm is anticipated or occurs, States and/or their lunar stakeholders should report to the scientific community and to the UN Secretary-General.[26]
8. Lunar stakeholders should choose and use efficient mining methods to not waste lunar resources, such as lunar water ice resources.

c) Future Ideas on Waste management

a) States are encouraged to draft joint environmental protection frameworks for lunar activities as well as develop common protocols on waste recycling on the Moon. All lunar

[22] The Moon Agreement 1979. Art. 7, para. 1.
[23] COCOSL. Article IX of the OST, para. 4.
[24] COSPAR's Planetary Protection Policy. URL: https://cosparhq.cnes.fr/assets/uploads/2019/12/PPPolicyDecember-2017.pdf; https://cosparhq.cnes.fr/assets/uploads/2021/01/Research_Outreach_PPP_2020.pdf
[25] The Moon Agreement 1979. Art. 7, para. 2.
[26] The Moon Agreement 1979. Art. 7, para. 3.

stakeholders, public and private, should be held responsible for their actions in accordance with principles of international space law, including the principle of international responsibility of States for national activities.[27]

b) Waste recycling includes but is not limited to the processing of biological, chemical, and other materials as well as space debris.

c) ISRU waste needs to be placed in such a way that it does not contaminate or damage unexplored lunar resources or other lunar assets.

d) ISRU should not make lunar dust harmful to others, whether it is in the process of digging, transporting or manufacturing.

e) Waste recycling is recommended to include in environment impact studies.

f) Environmental impact mitigation measures should be implemented and strongly amortized inside economically sustainable value chains by lunar stakeholders.

[Caveat: paragraph 3.6.3 is for initial working suggestions only. Guidelines 3.6.3.2 to 3.6.3.6 are already encompassed in the prior section on debris. Furthermore, as a matter of methodology, to begin prescribing guidelines on ISRU years before pilot plants are designed would be premature. Developing such guidelines before the methods are designed could lead to guidelines that are irrelevant or unnecessarily constraining. At the same time, regulatory clarity (or lack thereof) is an important criteria to develop sustainable business models.]

[27] The Outer Space Treaty 1967. Art. VI.

PART C: Interoperability

Table of Content

Definition

Interoperability refers to the development of common standards of design, manufacture and construction and/or operations to enable software and hardware components to be interchanged or operated in conjunction, to facilitate international cooperation, recycling and repurposing.

1. Avionics and computer components.

1.1. Description

Avionics is a conjunction of the words aviation and electronics. It is used to describe the electronic equipment found in modern aircraft.

1.2. Historical / Heritage Systems

The history of avionics is the history of the use of electronics in aviation. Both military and civil aviation requirements contributed to the development.

The term "avionics" was not used until the 1970s. For many years, aircraft had electrical devices, but true solid-state electronic devices were only introduced in large numbers in the 1960s.

The development of aircraft reliability and use for civilian purposes in the 1920s led to increased instrumentation and set in motion the need to conquer blind flight—flight without the ground is visible.

In the 1930s, the first all radio-controlled blind-landing was accomplished. At the same time, radio navigation using ground-based beacons expanded

a) Exploration Systems Project (ESP)

ESP is building a core avionics and software system for the Descent and Transfer Elements of the Human Landing System to land humans on the Moon.

21. The Customer Avionics Interface Development and Analysis (CAIDA) - May 3, 2018.

This supports the testing of the Launch Control System (LCS), NASA's command and control system for the Space Launch System (SLS), Orion Multi-Purpose Crew Vehicle (MPCV), and ground support equipment. The objective of the semester-long internship was to support the day-to-day operations of CAIDA and help prepare for the verification and validation of CAIDA software.

https://ntrs.nasa.gov/api/citations/20180002666/downloads/20180002666.pdf

a) Space Shuttle Program Primary Avionics Software System (PASS) Success Legacy

1. This reviews the avionics software system on board the space shuttle, with particular emphasis on the quality and reliability. The Primary Avionics Software System (PASS) provides automatic and fly-by-wire control of critical shuttle systems which executes in redundant computers. The charts given show the number of space shuttle flights vs time, PASS's development history, and other charts that point to the reliability of the system's development. The reliability of the system is also compared to predicted reliability.

1.3. Analysis and Lunar Perspective

Lunar Surface Systems Software Architecture Study: Interoperability

> This report is part of an overarching Lunar Surface Systems (LSS) Software Architecture Trade Study that identifies candidate architectures for the key software that will be used for each LSS Element (e.g., spacesuit, vehicle, robot, habitat).
> Lunar Surface Systems Software Architecture Study: Interoperability

2. Communication and navigation

2.1. Description

Communication links are the lifelines to spacecraft, they provide the command, telemetry, and science data transfers as well as navigation support. Navigation may be considered the art of directing the movement of a vehicle from one place to another. In today's context, it can be formally defined as the determination of a strategy for estimating the position of a vehicle along the flight path, given outputs from specified sensors.

2.2. Historical / Heritage Systems

a) Near Earth Network (NEN)

> The NEN is composed of more than 14 ground stations, comprising more than 25 antennas, worldwide. These upload and download information to and from spacecraft while they are within direct line of sight of the antenna, crossing from horizon line to horizon line.

b) The Deep Space Network (DSN)

> The DSN is composed of ground-based antennas and ground stations around the world. The DSN's antennas are huge – as much as 230 feet (70 meters) in diameter – and are placed at three key locations every 120 degrees around the globe, Madrid, Spain; Canberra, Australia; and Goldstone, California.

c) Space Network (SN)

> This currently transmits most human spaceflight data, including astronaut communications with Mission Control and even data about the spacecraft's health and telemetry. Data from science and technology experiments also come down to Earth through the SN.

d) THE LORAN SYSTEM

> The LORAN (Long-Range-Navigation) is a position fixing aid. It operates on a single frequency of 100 Khz and has a long range (greater than 1200 km). The latest version of this system called LORAN-C is very widespread, having many chains throughout the continental USA, much of Europe and the Middle East.

e) CHAYKA

> Chayka is a Russian terrestrial radio navigation system, similar to Loran-C. It operates on similar frequencies around 100 kHz and uses the same techniques of comparing both the envelope and the signal phase to accurately determine location.

f) Lunar Exploration Ground System (LEGS)

The mission of the 18-meter class Lunar Exploration Ground System (LEGS) is to provide direct-to earth communication and navigation services for missions operating in the cisLunar and Earth-Sun Lagrangian regimes. There will be three sites spaced equally around the Earth. The Ground sites will utilize CCSDS Modulation and coding schemes for forward and return data.

2.3. Existing conventions or standards

Space Communications and Navigation (SCaN)

SCaN has developed a set of Standard Services which are inherent to the current functional capabilities of the SCaN networks without modification. There are little-to-no modifications/dependencies on the development of new functions within any of the SCaN networks for standard services

Space Communications and Navigation (SCaN) Mission Operations and Communications Services (MOCS)

2.4. Analysis and Lunar Perspective

Two of NASA's space communications networks will potentially play a key role in making exploration of these distant destinations possible. Current robotic missions on the Moon, such as the Lunar Reconnaissance Orbiter, commonly use the NEN to transmit data to and from Earth. With its global network of ground-based tracking stations, the NEN can support missions from low-Earth orbit to lunar orbit and beyond.

LunaNet will provide users with four services: networking; positioning, navigation and timing; detection and information; and science. With LunaNet in place, users will experience an operational environment similar to that experienced by internet users on Earth. LunaNet is intended to be entirely interoperable and will be created by NASA, other government agencies, academic institutions, and the commercial aerospace industry.

2.5. GEGSLA Guidelines on communication and navigation

Interoperability at the Moon is of absolute importance.

In September 2021, the LunaNet team published draft interoperability specifications as a starting point for technical discussions among industry and government experts from around the world.

The goal is a set of standards that can enable an open, evolving, cooperative lunar communications and navigation architecture. Draft LunaNet Interoperability Specification

This can stand as a foundational framework to be built upon but should not be limited to entities in a single country.

3. Rendezvous and docking systems

Androgyneous Berthing Mechanisms

3.1. Description

Androgyneous docking systems allow for the interoperability of spacecraft, spacesuits and surface vehicles without relying on binary docking mechanisms (such as active/passive port mechanisms). These shall allow for crew and material transfers. Assuming multinational and multiagency operations on both the lunar surface and in orbit, a joint standard is regarded as critical to allow a physical exchange of crew members or goods as well as for contingency situations.

3.2. Historical / Heritage Systems

Apollo-Soyuz Docking: Utilized by RKK Energia as part of the Androgynous Peripheral Attach System (Андрогинно-периферийный агрегат стыковки) in 1975 for enabling the docking between the Apollo. Despite differences between the American and Soviet versions of the docking mechanism, they were still mechanically compatible.

- APAS-89 variant, APAS-95 variant for the MIR station, etc
- The Chinese space station is based on the Russian APAS-89/APAS-95 system with a mass of 310 kg for the androgynous variant.
- ISS berthing standard (IDSS, since 2016)

3.3. Existing conventions or standards

International Docking System Standard (IDSS, currently in rev E, available at: https://www.internationaldockingstandard.com/download/IDSS_IDD_Revision_E_TAGGED.pdf)

3.4. Analysis and Lunar Perspective

The existing IDSS is a mechanism that seems transferrable for lunar orbit docking mechanisms, dating back to 2010; however, the Interface Definition Document (IDD) does not address off-nominal procedures of workflows for operations. It also does not apply to dust-loaded surfaced under (reduced) gravity conditions.

The docking mechanism was developed under the authority of the International Space Station Multilateral Coordination Board. It is also planned to be implemented for the Lunar Gateway initiative.

3.5. GEGSLA Guideline on rendezvous and docking systems

The IDSS-IDD is a commendable template for an androgynous docking mechanism, however, it would have to be expanded for lunar surface conditions, in particular for docking vehicles for crew transfers both in lunar orbit and on the lunar surface. Dust mitigation techniques are a recommended field of study.

Specifically, to be excluded are docking mechanisms for suit-ports, as they have a significant impact on the spacesuit design and as such difficult to coordinate amongst agencies and industrial partners.

4. Outboard robotics, including lunar equipment

4.1. Description

Space-based robotics have been traditionally used by spaceships and orbit tasks.

Looking forward to moon activity and mining explorations robotics may find a new use and purpose for development. Not much has been done to develop robots that will be used in earth activities including moon activities or Mars activities. Any development of such robotic technology will rise from the demand of commercial or government groups and therefore will be used in specific tasks and closed loops.

4.2. Historical / Heritage Systems

Introduction

Space-based robotics have traditionally been tasked with robotic on-orbit servicing functions, but despite several decades of development since the 1980s, this has yet to come to pass. A new application of space manipulators has emerged—active debris removal. Much of the technological development in space robotics over this period is directly applicable to this new task and indeed, given that the more challenging aspects of on-orbit servicing are not required (namely, servicing tasks), the prospect of active debris removal can be met. All the kinematic, dynamic and control issues are identical—this includes the requirement for grappling the target and passivating it. In future Moon village robotics latching mechanisms, Servicing tasks will typically involve the deployment of power tools for bolt manipulation and the use of specialized tools for more challenging tasks such as cutting, taping and resealing.

We first consider a brief schematic of recent on-orbit space manipulators employed by the International Space Station (ISS) and thence proceed to describe the rise and fall of robotic on-orbit servicing missions. We then provide a comprehensive review of the growing space debris crisis and proposed solutions and last the topic of robotics in mining and other moon village activities.

Space manipulator robotics has played a significant role on the ISS, which has installed on it three manipulator systems: the Canadian Mobile Servicing System (MSS), the Japanese Experiment Module Remote Manipulator System (JEMRMS), and the European Robotic Arm (ERA). The MSS includes the 17 m long 7 degree-of-freedom Space Station Remote Manipulator System (SSRMS) with its relocatable base, which is comparable to the 11 m long 7 degree-of-freedom ERA with its relocatable base in contrast to the 10 m long 6 degree-of-freedom JEMRMS fixed to the JEM. Both SSRMS and ERA are symmetric about their elbows, with latching end effectors at the end of each three degree-of-freedom wrist enabling hand-over-hand relocatability. Both were designed for assembly and servicing, while JEMRMS was designed for experiment payload manipulation from a fixed location.]

4.3. Existing conventions or standards

OOS appears to have reached an impasse—much of the robotics technology has been developed, but there has been little in the way of commercial development. However, active debris removal has emerged as another application of the same technology which could potentially provide the final leverage to OOS as a space infrastructure capability. OOS itself also acts as a debris mitigation strategy—refuelling and servicing spacecraft at end-of-life will reduce the rate of creation of space junk.

Defunct parts may be replaced and/or upgraded, although this requires supply from Earth- though supply from lunar in situ resources remains an intriguing future possibility.

4.4. Analysis and Lunar Perspective

When considering the future needs in mining and science expeditions to the moon robotics will take a large part in maintaining and sustaining lunar activities space agriculture biowaste treatment and solar panel cleaning etc.

4.5. Recommended guidelines on outboard robotics, including lunar equipment

It recommended to develop guidelines on outboard robotics, including lunar equipment. These guidelines should include common parts and common software versions for the exchange of damaged robots without the need for long-duration waiting for both from the Earth.

5. Training of mission crews, harmonization of training methods in terms of safety.

5.1. Description

Both interoperability, as well as contingency situation scenario, may require collaboration between lunar crews. To reduce the risk of allowing external crews to interact with one's own astronauts, both the communication cultures and awareness of operational aspects and engineering designs may be essential. Hence, already during training, a harmonization of how to interact with other crews, e. g. during analogue training activities may offer a cost-efficient pathway.

5.2. Historical / Heritage Systems

a) PANGEA/CAVE missions of the European Space Agency: these are established ISS-related training analogue missions allowing for inter-cultural training between astronauts. This could be considered a best-practice example of cross-training between agencies. However, the operational modalities, organizational insularity when it comes to inter-organizational collaboration and scale of activities are not yet compatibly with what might be required for extended lunar operations.

b) Similarly, NASA-led activities like the BASALT or the previous D-RATS missions allowed for limited international participation.

c) There is considerable experience in intercultural training in various grassroots activities with non-professional organizations like the Mars Society or comparable settings like Antarctic research stations like CONCORDIA, VOSTOK, McMURDO etc hosting international crews – although traditionally not formally involved in designing lunar exploration architectures, there is a considerable amount of experience and institutional knowledge to refer to.

5.3. Existing conventions or standards

Polar station crews undergo standardized training for decades to familiarize them with both the environment and basic understanding of polar operations. These are done in observance of established standards like the International Convention on Standards of Training, Certification and Watchkeeping, 1978 (STCW), supplemented by the Part C of the (Int. Maritime Organisation) IMO Guidelines focuses on Operational Procedures, Crewing and Emergency Equipment. Another example would be the guidelines published by the ISO technical committee on arctic operations (ISO/TC 67/SC 8, oil and gas sector).

5.4. Analysis and Lunar Perspective

Polar operations bear several similarities to lunar operations. Although there is a broad variety of crew purposes and tasks, engineering infrastructures etc in arctic activities, there is still a consensus on how to conduct training and minimum certifications for polar operations.

We suggest that these training regimes may serve as an inspiration for harmonizing astronaut crew training principles for safety.

5.5. Recommended guidelines on training of mission crews, harmonization of training methods in terms of safety.

Guidelines are recommended as follows, considering both the need for cross-agency and intercultural training, complemented by the need for at least establishing a basic understanding of foreign engineering principles to enable mutual support in contingency situations. This training should commence during the training on Earth. Similarities in (ant)arctic operations as a model for lunar activities and hence would suggest the adaptation of those established standards to planetary surface activities.

6. Space Debris Disposal

6.1. Description

Inevitably, anthropogenic space debris will be part of the lunar ecosystem, both in the orbit and on the surface. Contrary to spaceflight operations eg in Low Earth Orbit where the emergence of space debris is a recognized challenge for the safe conduct of spaceflight operations, lunar surface operations may have additional characteristics pertinent to the Moon, such as mining operations, establishing permanent large-scale human/robotic outposts, extensive landing/launching operations potentially leading to a debris production beyond what is observed in LEO today.

In order to preserve the pristine lunar environment, minimize the need for transferring materials, reduce the hazards for lunar surface operations and other considerations, the need for space debris disposal is evident.

So far, the international consensus on space debris mitigation on Earth is yet to be established as part of numerous space situational awareness and mitigation efforts. Extrapolating this to the Moon is challenging as long as there is no agreement foreseeable in LEO.

6.2. Historical / Heritage Systems

As early as 1994, the UNOOSA has issued the "Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space" (introduced at the 31st STSC session, A/AC.105/571, paras. 63-7), which led to a general endorsement of the guidelines in 2007. A set of mitigation guidelines has been developed by the Inter-Agency Space Debris Coordination Committee (IADC), reflecting the fundamental mitigation elements of a series of existing practices, standards, codes and handbooks developed by a number of national and international organizations.

6.3. Existing conventions or standards

UNOOSA "Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space"

6.4. Analysis and Lunar Perspective

Current space debris mitigation conventions are focused on LEO and GEO operations; nevertheless, more recent lunar space debris models project similar behavior and developments in lunar orbit with the increase of human activities. All guidelines currently observed rely on a voluntary observance of mitigation strategies.

As with the example in LEO and GEO, it is yet to be seen if any international mitigation regulations will take their grasp beyond being observed voluntarily. However, there are also economic considerations that may lead to early adoption of those standards: If the risks presented by space debris on lunar orbit or the lunar surface outweigh the economic benefits (e.g. the risk of losing a lunar reconnaissance satellite by space debris), operators may be encouraged to lower their space debris contributions. However, the discrepancy between a single operator's decision to potentially lower his economic expectations for the benefit of everyone calls for a high degree of consensus – exemplified in economic social theories as to the "tragedy of the commons".

6.5. Recommended guidelines on Space Debris Disposal

Guidelines are recommended as follows, considering the risks and projected problems emerging from space debris both on the surface of the Moon as well as the lunar orbit. Given the challenges of agreeing on SSA and space debris mitigation measures on Earth, these models may be extrapolated to lunar operations.

However, in order to facilitate the adoption of future debris mitigation regulations, societal education about those risks can be promoted by space actors including GEGSLA. Similar to the emergence of an ecological movement in our history to preserve natural resources: as it may take decades until the acceptance that the lunar environment is worth protecting, it is recommended to start already now to promote this mindset, which may ultimately evolve into regulatory standards protecting the lunar environment.

7. Mechanical, Pneumatic-Hydraulic, Electric

7.1. Description

This broad topic area covers a range of mechanical and electrical interfaces, including standardized features to facilitate the movement of items, the electrical interface for systems such as voltage and current standards, and the physical interface for transferring electrical power.

7.2. Historical / Heritage Systems

Some example heritage systems in the space domain are the International Space Station (ISS) grapple fixtures. There is a standard without power, the Flight-Releasable Grapple Fixture (FRGF), and a standard with power, the Power Data Grapple Fixture (PDGF). The ISS also has a set of power standards for 120 V DC. 28 V DC is another widely used power standard, but there is not necessarily an internationally accepted standard. It is left to future work to incorporate a 28 V standard into the ISS standards.

On Earth, some mechanical example systems are standardized shipping containers for ocean shipping and forklift attachments features on cargo pallets. There are the household electrical outlet standards, both for voltage and current, and for the mechanical plug. There are also standards for voltage and current for long-distance power transmission.

7.3. Existing conventions or standards

- International Space Power System Interoperability Standards (ISPSIS): https://nasasitebuilder.nasawestprime.com/wp-content/uploads/sites/45/2019/09/power_baseline_final_3-2019.pdf
- International External Robotic Interoperability Standards: https://explorers.larc.nasa.gov/HPMIDEX/pdf_files/17C_Robotics-020918_R1.pdf
- Space Plug-and-Play Architecture Standard: 28V Power Service (AIAA S-133-5-2013): https://arc.aiaa.org/doi/book/10.2514/4.102332

7.4. Analysis and Lunar perspective

It is recommended that the lunar community adopt already-established international standards wherever possible. In addition, the lunar environment such as dust may force a need to develop a lunar-unique standard. Lunar operations will also likely involve more interoperable activity at a smaller scale than a space station, and this scale of activity also needs standards. At this time, there is not a clear need for pneumatic or hydraulic standards given their complexity and lack of use in the space domain.

7.5. Recommended guidelines

Guidelines are recommended as follows: there should be two sizes of grapple fixtures to facilitate the movement of items. The first, larger size is the ISS Flight-Releasable Grapple Fixture (FRGF).

At least a second standard should be developed based on the FRGF but at a smaller size to accommodate the small 100 kg class robotic landers and rovers expecting to operate on the lunar surface. It may be necessary to have a third even smaller standard around the 1 kg class.

The 120 V ISS electrical standard is recommended to be used on the lunar surface, particularly for high power systems and crewed systems. A similar standard, but 28V DC, also needs to be developed and accepted by the international community. Dust-resistant physical interfaces (plugs) need to be developed and accepted by the international community for 28 V and 120 V.

While it is not an immediate need, the community should consider a shipping container standard.

8. Power Supply Systems

8.1. Description

This topic area covers electrical interfaces for providing power, such as voltage and current standards, and the physical interface for transferring electrical power to an element.

8.2. Historical / Heritage Systems

Some example heritage systems in the space domain are the International Space Station (ISS) power standards for 120 V DC. 28 V DC is another widely used power standard, but there is not necessarily an internationally accepted standard. It is left to future work to incorporate a 28 V standard into the ISS standards.

On Earth, there are the household electrical outlet standards, both for voltage and current, and for the mechanical plug. There are also standards for voltage and current for long-distance power transmission.

8.3. Existing conventions or standards

- International Space Power System Interoperability Standards (ISPSIS): https://nasasitebuilder.nasawestprime.com/wp-content/uploads/sites/45/2019/09/power_baseline_final_3-2019.pdf
- Space Plug-and-Play Architecture Standard: 28V Power Service (AIAA S-133-5-2013): https://arc.aiaa.org/doi/book/10.2514/4.102332

8.4. Analysis and Lunar perspective

It is recommended that the lunar community adopt already-established international standards wherever possible. The lunar community should also take advantage of this time to internationally standardize interfaces that don’t currently have a widely accepted standard, such as 28V power. Lower voltage standards could be considered, but it is reasonable for all elements operating on the lunar surface to take 28V DC as input power and convert it from there. It is expected that in the future there will need to be additional standards for things such as high-power transmission, particularly for industrial-scale activity such as in situ propellant product.

8.5. Recommended guidelines on safety support means of crewed missions

Guidelines are recommended as follow, while these recommendations only cover the electrical interface parameters. Mechanical interfaces for electrical power connections are covered by Item 1.2.1 Mechanical, Pneumatic-Hydraulic, Electric.

It is recommended that the 120 V International Space Station (ISS) electrical standard be used on the lunar surface, particularly for high power systems and crewed systems. A similar standard, but 28V DC, also needs to be developed and accepted by the international community.

While it is not an immediate need, the community should consider standards for high power transmission to support industrial-scale activity.

9. Safety Support Means of Crewed Missions

9.1. Description

This topic area covers any process or interface whose purpose is to help protect the safety of humans on the lunar surface.

9.2. Historical / heritage systems

The Outer Space Treaty Article V states that "the astronauts of one State Party shall render all possible assistance to the astronauts of other States Parties" and that "States Parties to the Treaty shall immediately inform the other States Parties to the Treaty or the Secretary-General of the United Nations of any phenomena they discover in outer space, including the moon and other celestial bodies, which could constitute a danger to the life or health of astronauts." Standards for providing assistance and rescue in space that are outside the boundaries of a particular program like the International Space Station don't exist. Perhaps the best Earth-analog would be international maritime rescue conventions and guidance.

9.3. Existing conventions or standards

Outer Space Treaty Article V: https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/outerspacetreaty.html

International Maritime Rescue Federation collection of International Maritime Organization Documents that are relevant to search and rescue: IMO Documents | International Maritime Rescue Federation

9.4. Analysis and Lunar perspective

Activity on the lunar surface may be the first need for the definition of basic international safety standards. Given the possible complexity of interoperable standards for life support systems and medical care, it may be best to focus initial standards on key items to facilitate meeting the obligations of Article V of the Outer Space treaty. Key items include emergency communication standards, the sharing of safety zone location data for operations, and the sharing of information on hazards. In cases of distress, it is likely best for priority to be placed on getting the crew into an airlock as opposed to trying to interface to Extravehicular Activity (EVA) suits.

9.5. Recommended guidelines on safety support means of crewed missions

Guidelines are recommended as follows: an international communication standard be developed for lunar surface operations, including the definition of emergency frequencies, the broadcasting of safety zone location data, and the format of S.O.S. messages. Furthermore, an international safety database to be developed to log any dangerous phenomenon on the surface of the moon per Article V of the Outer Space Treaty.

10. Deployment Systems

10.1. Description

Costs reductions are possible through the introduction of standards and guidelines for interfaces, interoperability, compatibility, and control principles. This topic area covers interoperability requirements for deployment systems to provide access to the Moon Village technical components being developed.

10.2. Historical / heritage systems

The primary example of space deployment systems is the CubeSat standard for dispensers.

10.3. Existing conventions or standards

- ISO 17770:2017 Space systems — Cube satellites (CubeSats): https://www.iso.org/standard/60496.html

10.4. Analysis and Lunar perspective

There is a wide range of possibilities for the definition of deployment systems for the lunar surface, across a range of sizes and capabilities. It is expected that these systems will need to be defined as the scope and complexity of lunar operations increase. It may be best to start small and build from there. Today, a standard for the deployment of small payloads from lunar landers to the lunar surface similar to the CubeSat dispenser standard may be the most useful given the expected scope of activity in the near term.

10.5. Recommended guidelines on deployment systems

Guidelines are recommended as follows: to develop a standard for the deployment of small payloads from lunar landers to the lunar surface similar to the CubeSat dispenser standards is recommended.

PART D: Lunar Governance

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a) Defining lunar governance

Lunar governance can be defined as systematic and comprehensive management and decision making on issues related to the full range of lunar activities, consistent with the principles enumerated in the Outer Space Treaty and other relevant aspects of international law. Through multi-stakeholder engagement and dynamic interactive processes, lunar governance will enable the sustainable exploration and use of the Moon.

Governance is the sum of all the ways through which members of the global society manage shared problems. It is a mean to promote cooperation between members and a process capable of producing effective results in the management of global issues.

By expanding the definition of governance from Earth affairs to Moon activities, lunar governance is concerned with management of shared problems related to the use and exploration of the Moon and should be developed to ensure peace and security in outer space, to maintain the sustainability of lunar activities, and to benefit all humankind.

b) Responsible lunar governance

Building on the concept of lunar governance, responsible lunar governance will aim to facilitate responsible behaviors among lunar actors. Responsible lunar governance will be consistent with existing international law, including the Charter of the United Nations and the Outer Space Treaty, and will be guided by a wide range of additional hard and soft law instruments as appropriate (see the section on "Instruments for developing responsible lunar governance" below).

c) Stakeholders in lunar governance

Responsible lunar governance emphasizes notions of openness, inclusiveness, and broad participation, using multi-stakeholder engagement to manage and decide on issues related to sustainability of lunar activities. Therefore, in the lunar context, stakeholders include not only traditional space actors but all actors both directly and indirectly involved in lunar activities, including actors along supply chains as well as emerging actors.

To afford multiple stakeholders meaningful participation in Lunar Governance, discussions involving lunar activities should take place at the levels of intergovernmental organizations, academia, non-governmental organizations, industry, and civil society, in addition to traditional fora such as inter- agency fora, inter-governmental organizations, and UNCOPUOS.

Lunar governance is intended to include all participants of space activities. The Outer Space Treaty recognizes the use and exploration of the Moon as the province of (hu)mankind and establishes that they shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development.[28] Therefore, the involvement of developing countries in lunar governance is essential to ensure that their interests and specific needs become

[28] OST Article I

part of the agenda. At the same time, their engagement can be an enabler for increasing compliance with the international framework.

d) A common approach to responsible lunar governance

At the international level, responsible lunar governance is an integral part of global space governance, defined by the United Nations General Assembly as "the institutional framework for the governance of international cooperation in using outer space for peaceful purposes."[29] To promote global space governance, the UN General Assembly adopted *The "Space2030" Agenda: space as a driver of sustainable development* in 2021 as a strategic vision and called upon Member States to implement it. Overarching objective 4 of *The "Space2030" Agenda* is to "build partnerships and strengthen international cooperation in the peaceful uses of outer space and in the global governance of outer space activities." In this regard the activities and outcome of the GEGSLA will contribute not only to the development of lunar governance but also inform the discussion of global space governance at large.

e) Essential elements of responsible lunar governance

Global space governance as a framework includes the United Nations treaties and principles on outer space, the relevant guidelines adopted by the Committee and the resolutions on outer space adopted by the General Assembly, as well as supporting efforts undertaken at the national, regional, and global levels, including by entities of the United Nations system and international space-related entities.[30]

Lunar governance can build upon the aforementioned elements to arrive at a framework that incorporates the concepts of peace, security, cooperation, and mutual understanding in the exploration and use of the Moon and its resources.

Lunar governance seeks to identify synergies, converging interests and expectations, balance current diverging needs and interests as well as the needs and interests of future generations, and is concerned with current and future stakeholder interaction.

Recognizing that responsible behavior can be context-specific, responsible lunar governance will require a complex and adaptive framework facilitating an efficient decision-making process that seeks to:

> 1) Respect general principles and norms such as those enshrined within international space law and soft law instruments, including but not limited to peaceful uses, due regard, non-interference, mutual understanding, non-discrimination, equality of access, freedom of exploration, non-appropriation, information sharing and transparency, and international cooperation;

[29] A/AC.105/1137
[30] See A/AC.105/1137, paragraph 7

2) Ensure predictability, accountability, fairness, inclusiveness, transparency, coherence and synergy in a manner that fosters healthy competition among stakeholders;

3) Reconcile several variables relevant to lunar activities through an adaptive process, such as, *inter alia*, governmental, intergovernmental, and non-governmental actors interacting through public-private-partnerships, private funding initiatives and new technologies;

4) Operationalize this multilaterally agreed upon framework for the benefit of all humankind with the preservation of the lunar resources and environment and the sustainable lunar exploration and utilization as its key elements.

This should include a consensus-based, effective method of decision-making that ensures collective responsibility and the effective and safe coexistence of all involved lunar stakeholders.

In creating this framework, the full spectrum of lunar activities, as well as the whole life cycle of lunar activities (from R&D to end-of-life) should be considered.

6. Instruments for developing responsible lunar governance

Notwithstanding the potential need for a comprehensive and adaptive multilateral framework to address needs and interests that will be identified as lunar activities evolve, operationalization of responsible lunar governance shall be guided by the existing legal framework, and participants should act in accordance with principles, norms, and rules applicable to the use and exploration of outer space, that arise from instruments such as:

a) The Outer Space Treaty, as the fundamental instrument to rely upon: common interest, freedom of access, use and exploration shall be starting points for responsible lunar governance, which shall continuously seek the maintenance of peace and security, and promote transparency, cooperation and understanding. Though subsequent State practice and agreements will interpret and elaborate some of OST's provisions within the lunar context, its principles and norms shall be references for the development of responsible lunar governance.

b) The Moon Agreement could be considered as the most [The Moon Agreement is a potentially] relevant legal instrument to deal with lunar activities: built upon the intergenerational perspective of sustainability, it provides valuable suggestions for the operationalization of responsible lunar governance in areas including in-space resource utilization (ISRU), environmental protection, and equitable sharing of benefits.

c) The UN Charter: especially with regard to international peace and security, pacific settlement of disputes, friendly relations, equal rights, self-determination, international cooperation, and respect for human rights and fundamental freedoms.

d) The Rescue Agreement, the Liability Convention, the Registration Convention and other relevant international treaties.

Other instruments that provide reference and guidance for the development of responsible lunar governance, as indicative of shared expectations, are:

e) The Long-Term Sustainability Guidelines, *Space 2030 Agenda,* and other soft law instruments.

f) Governance initiatives, such as the Building Blocks for the Development of an International Framework on Space Resource Activities, The Moon Village Best Practices for Sustainable Lunar Activities, and the Effective and Adaptive Governance for a Lunar Ecosystem (EAGLE) Report.
g) The Artemis Accords and other non-legally binding international agreements.
h) International technical and other relevant standards.

7. Institutions for responsible lunar governance

Implementing responsible lunar governance may require institutional innovations. The question remains whether new international institutions are needed to carry out this function, or whether it can be delegated to existing institutions.

In the short term, it may be possible to place the administration of lunar governance with an existing international institution (or institutions), such as the International Space Exploration Coordination Group (ISECG) and/or a reinvigorated International Space Exploration Forum (ISEF), working in collaboration with UNOOSA and COPUOS.

In the longer term, it is possible that a dedicated international institution may be required in order to provide permanent channels of debate between the multiple interested actors, improve decision-making processes and enable better results for the participants. The International Telecommunication Union (ITU) or the International Atomic Energy Agency (IAEA) might serve as possible models.

8. Implementation of Responsible Lunar Governance

National and international mechanisms (national legislation and policy, international treaties, etc.) are one component of the implementation of lunar governance. States also have a role to play in monitoring national activities.[31]

Responsible lunar governance is intended to cast a broader net by including not only state actors but all lunar actors, recognizing that most of these actors will likely participate in lunar governance through their national administrations and agencies. This is intended to foster consistency between the policies adopted by these different actors.

Clearly outlining advantages of participation, as well as the costs of non-compliance, may assist in getting buy-in for participation. Identifying shared interests, goals, and expectations and implementing mechanisms that will guide behaviors and encourage participants to comply will help to achieve better overall results.

[31] Art. VI of the Outer Space Treaty

ANNEX II
Future Issues

A Report from the GEGSLA Observers on Future Issues of the Recommended Framework Document

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a) Introduction

Objectives:

This Annex II, assigned to Observers of GEGSLA, contains a summary listing of matters pertaining to the peaceful, safe, and sustainable development of lunar activities, which, whilst not being assessed in the technical guidelines in the Recommended Framework Document main body and Annex I, nevertheless would require some international agreement, but not in the timeframe envisioned under the Recommended Framework document. These matters will therefore remain to be resolved in a later time frame.

Mindset:

The contents of this Annex II, assembled by Observers of GEGSLA, are not intended to overlap with matters considered in Annex I and are deliberately limited to only a brief description and possible implications, carrying no implied priority order. GEGSLA's deliverables being intended for UNCOPUOS governance with the consensus process as preferred mechanism, the Observers' responsibility is to make sure Annex II gets to the floor of UNCOPUOS for acknowledgement and future resolution of said matters. It is furthermore hardly possible and even less desirable for Observers to offer prematurely a prescriptive path to political and legal resolution at this time, while neither would it be appropriate for Members to forward any prescriptive Annex II language which Members would not have developed and validated themselves in the first place. As Observers acknowledge that GEGSLA is their route to the UNCOPUOS chamber floor, they must therefore work towards the acceptance of Annex II language, so that Observers may achieve their aim of getting these Annex II matters onto the chamber floor in Vienna.

b) Benefits For Humanity

Identify the potential benefits to the inhabitants of the Earth from use of the Moon as a training ground for the longer-term development of economic resources from solar system objects.

Design and operationalize concrete international mechanisms that address the social dimension of sustainability by sharing benefits of lunar activities with the whole society, elaborating Article I, para. 1 OST- including mechanisms to foster the involvement of developing countries in Lunar activities, ensuring inclusiveness, while not threatening the commercial attractiveness of those activities.

Ensure that geographically diverse stakeholders and emerging companies across the spectrum of economic development are granted access to value chains and are included in value generation and sharing processes that were until recently almost exclusively reserved to dominant space actors.

Ensure that people everywhere, gain equitable access to the means of creating value and being able to share it.

For all stakeholders, facilitate a key enabler of that process which is the access to the insights derived from data. Accelerate open source and collaborative creation, extraction, valorization, and equitable sharing of value and, therefore, benefits.

Encourage use of the Moon Village concept in solving Earth global challenges.

c) Sustained Lunar Economy

Supporting the private sector in outer space is excellent public policy. Without the private sector investing resources, talent, creativity, and enthusiasm to sustain human activity in space, not much may happen. But the private sector likewise needs to honor essential public policies, like the Outer Space Treaty and any other treaty/agreement that their host country has signed. In particular, including and not limited to the right set of incentives, private actors may need to commit to sharing and cooperation, rather than exclusion and confrontation, concerning in situ resources. The following is a list of objectives toward economic sustainability.

To the extent not previously covered under Annex I:

1. consider the establishment of an initial testing zone for Lunar industrial activities to limit the potential for environmental damage, and as a result, establish an agreement between the different countries for good uses of these areas.

2. support the introduction of common infrastructure elements on the Moon, including shared landing and take-off sites, and shared roadways, along with the elaboration of mechanisms to foster a responsible use of facilities among the different crews.

3. support the provision of common navigation and communications systems for use on the Moon.

4. ensure that Lunar space tourists receive the same protections under international law that are afforded to governmental astronauts.

Develop mechanisms for sharing in situ resources and the discovery of resources. Develop mechanisms for the resolution of disputes, including commercial disputes, between States and/or their nationals, including consultation, arbitration, and mediation.

In a relevant context of cislunar and lunar economic development, to the extent not already covered at scale by already existing Earth-based services, support the introduction of Lunar banking and currency management arrangements.

Support the development of cislunar and lunar wholesale payment systems and commercial transactions infrastructures and processes, which leverage, at scale, adequate cislunar and lunar data, fintech, and legaltech architectures.

Maintain balance between the requirements of a Machine-to-Machine economy and the needs of human demographics for retail payment and personal finance, with an emphasis on open-source data access, valorization, and sharing.

- **Concept of ‘Priority Zones’**

i. Concept formulation: To the extent not covered under Annex I recommendations, develop mechanisms for the administration and recording of ‘Priority Zones’, with some limited time period validity, for commercial operators to be able to explore for economically accessible and exploitable lunar resources.

ii. Acknowledged friction: A question is to what extent the concept of ‘Priority Zones’ may be construed as conflicting with Treaty principles, which may lead to rejection, particularly if Zones are framed as ‘exclusive’. There seems to be at least two root causes for friction and likely rejection unless these aspects are carefully reconsidered. A first cause for friction is a process allegedly conflicting with the Treaty ban on appropriation. A second cause is the Treaty obligation to guarantee open access to all. That seems to suggest a design and resolution of a 'Priority Zone' mechanism is both dependent on and subsequent to the design and resolution of at least two other mechanisms: one as workaround for the non-appropriation principle that would enable a sustainable economic exploitation by a number of parties ; one that would offer a framework for access and benefit sharing that would in particular preclude two extreme scenarios: one operator free-riding halfway into the SRU cycle on another operator investment, and, one operator offering only crumbs at the SRU cycle end, to another operator also laden with decommissioning costs.

iii. Initial remediation: Data and the recording of operational, legal, and governance processes input and output, is the basis of lunar socio-economic activities. A permanent dynamic record of international activities on the Moon may constitute a basis to identify and track which stakeholders engaged in what activities, how, where, and when. It will take time to establish an assessment of lunar resources as per a rigorous mining methodology that qualifies and quantifies accessibility and exploitability of such economic resources in the early phase, until such time when it is determined to which extent significantly more sizable investments may be justified. It might be useful to design, in lunar exploration early phase, frameworks enabling to first and foremost establish a record, and consider to which extent some non-appropriation principle workarounds and access and benefit sharing mechanisms may then be incrementally developed for operational architectures of 'Inclusive Priority Zones'.

- **International Framework of Governance**

Establish an international framework of governance, including appropriate procedures to govern the exploitation of the natural resources of the Moon as such exploitation is about to become feasible.

The main purposes of the international framework should include:

i. The orderly and safe development of the natural resources of the Moon;
ii. The rational management of those resources;
iii. The expansion of opportunities in the use of those resources;
iv. An equitable sharing by all States Parties in the benefits derived from those resources, whereby the interests and needs of the developing countries, as well as the efforts of those countries which have contributed either directly or indirectly to the exploration of the moon, should be given special consideration.

Finally, to the extent not previously covered under Annex I-II-III, aim at public and private actors committing themselves to protect the lunar environment, that "magnificent desolation" (Buzz Aldrin), for the use and inspiration of both current and future generations. Aim at developing and implementing any relevant additional international governance frameworks that may be required to that end, including and not limited to incentive systems for behavior better than required.

d) Human Interaction

i. Encourage the provision of safety and security, including rescue and emergency support services, for Lunar occupants.
ii. To the extent not previously covered under Annex I (Safe Operations/Lunar Environmental Protection), establish interference protection and dispute settlement mechanisms, including arbitration and mediation.
iii. To the extent not previously covered under Annex 1, develop mechanisms for the sharing of finite common resources on the Moon (e.g. lunar water, power during Lunar night, oxygen, etc.), in particular in situations endangering the lives of groups of lunar occupants, whereas other groups are in a position to rescue.
iv. Develop mechanisms so achievements of mission critical TRLs (Technology Readiness Levels) are given consideration for life sciences, space medicine, and human resilience, as much as they are given for machine-oriented achievements.
v. Acknowledge issues for consideration in life sciences and space medicine including and not limited to: food production; bio-regenerative life support system design (BLSS); muscles and bones degradation in reduced gravity; cardiac health; SANS (Spaceflight-Associated Neuro-Ocular Syndrome); and radiations.
vi. Plan and regulate for the hypothesis that the Moon and cislunar space may also become a hub for human-operated long duration space travel (LDST) toward the rest of the Solar System, while the following may be noteworthy of consideration: LDST specific medicine ; gynecologic and obstetric aspects of LDST ; risks and benefits associated with taking the combined oral contraceptive pill during LDST ; treatment of LDST-induced antibiotic resistant E.Coli Infections ; role of precision medicine in LDST; use of hibernation for humans in LDST ; and the ethics of conducting genetic modifications to improve survival in LDST. For both short duration Moon operations and LDST, regulate training for mental resilience. Develop systems and procedures for persons with disabilities in SD and LDST.
vii. Consider a system to guarantee Moon and cislunar workers long term healthcare and access to state-of-the-art space medicine, when in space and back on Earth. Include dispositions as part of their contractual relationship with employers such as occupational hazards and profession-induced physiological and mental health issues. Consider creating Moon and LDST-oriented ‘Space Labor Regulations’. In order to enable as a first step recommendations from the World Health Organization, provide the WHO with the necessary mandates and capacities to develop international space health standards.
viii. Aim at such a future outer space labor regulatory framework not colliding with fundamental labor standards and other relevant standards related to decent work, that humanity has struggled to recognize and still struggles to implement on Earth.
ix. Promote data-driven law and governance with a human-centered purpose of empowering individuals operating in the Earth-Moon ecosystem. Improve all individuals’ inclusiveness in access to justice and legal outcomes in a context dominated by governments and corporations. If law and governance in the Earth-Moon ecosystem are to be optimized through the use of technology, they may be optimized to meet the needs of individuals and of the Moon and cislunar society.
x. Encourage the protection of individual rights. Consider endorsement of the Universal Declaration of Human Rights. Acknowledge the close relation between Human Rights and the future development of international labor standards related to outer space, which is likely to intersect with the mandate of the ILO.

xi. Develop and implement the concept of "The Moon as a Laboratory of Peace"[32]. Aim at leaving behind on Earth the roots of all human warfare, by either keeping cislunar and lunar space unaffected by the consequences of 'geo'-politics, or, at a minimum, establishing and enforcing architectures of pre-emptive deconfliction.

Note: while this section originally applied to the resolution of human disputes more of a personal nature, due to the entanglement between the personal and the economic, there is inevitably some duplication of dispute resolution language with the prior section on economic relations.

e) Other

To the extent not previously covered under previous technical guidelines of Annex 1, establish arrangements to preserve the Lunar far-side for purposes requiring the absence of terrestrial radio emissions (e. g. radio astronomical observations).

Take into serious consideration the risk of harmful interference linked to "microbial diffusion". As human, animal, and plant life develops on the Moon through sustainable communities, either on lunar surface and vicinity, or in underground lava tubes, the Moon's ecological environment will change dramatically. In the presence of radiation in the environment, determine the spread and mutation potential of 'microbial diffusion'. Adapt provisions of planetary protection relevant to both living ecosystems on the Moon and the biosphere and humankind back on Earth, in order to regulate and mitigate potential harmful interferences.

Take into serious consideration the risk of harmful interference linked to "nuclear contamination". Due to the amount of energy needed for long term sustainable lunar communities, solar power alone is unlikely to be sufficient to support industrial, logistics, and human activity. The inevitable use of nuclear power raises waste treatment and contamination risk issues. Determine a most effective way to protect against nuclear contamination. Draw the necessary contingency measures in case of a nuclear power unit failure, in order to regulate and mitigate potential harmful interferences among Moon areas of relevant activities.

Thrive to build trans-disciplinary teams that understand and respond to each other's needs and objectives. Ensure consistency of current and projected legal requirements and governance framework vis-à-vis current and projected scientific and technological readiness levels, as well as realistic trade and investment demand drivers and constraints. Firm up definitions and binding degrees for the linkage between harmful interference and legal requirements. Ensure that legal requirements and governance frameworks do not get quickly outdated due to scientific and technological progress as well as established trade and investment practices.

Acknowledge that processes exist under customary international law for settlements to seek recognition as sovereign states while deferring any specifics on how such a process would work on the Moon or elsewhere.

f) Conclusions

Starting from objectives and a mindset as described in the Introduction, Observers estimated in their assumptions that they would be better off taking a step back and leaving the Appendix 2 items as simply 'issues that will need resolution at a later stage'.

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32 (*) a concept initially coined by space lawyer and Member Prof Mark J. Sundahl.

Observers have formulated a number of issues, together with implications, over various items covering categories such as ‘Benefits for Humanity’, ‘Sustained Lunar Economy’, ‘Human Interaction’, ‘Other’. Their baseline remains a respectful acknowledgement of the Outer Space Treaty and Conventions principles, as pertaining to many such future expected issues of lunar activities governance. Observers executed their methodology refraining from attempts at taking the Annex II language too far: considering that, most of existing space governance and legal frameworks, should they undergo some form of evolution in the coming decades, may only do so once economic traction and diversity of responsible states, combined with the hard-earned operational experience of lunar activities by all stakeholders, reach a critical mass. Observers deem non advisable at this stage to try and fast-track solutioning of any particular issue by one “show-stopper” interpretation of Treaty language, that would solve any particular activities operational friction potentially conflicting with some Treaty principles, by expedient language that implies suppression of such activities as solution. Instead, Observers did acknowledge elements of friction and alleged conflict, analyzing root causes and initial remediation, as in the case of a ‘Priority Zones’ concept. Like a thousand miles journey starting with a single step, it is the Observers’ aim that such issues be validated for bandwidth and resolution at a later stage, through an effective international framework of governance.