Managing the Plume Effect for Sustainable Lunar Operations

60th Session of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space

Feb. 8, 2023

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www.forallmoonkind.org

For All Moonkind is a non-profit organization committed to **protect and preserve human history and heritage** in outer space.

Our **entirely volunteer team** of space lawyers and policymakers are working to develop reasonable and practical protocols that will balance development and preservation and include systems to select, manage and study relevant sites.

In so doing, we seek to **promote responsible and sustainable exploration and development of space**.

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The LTS Guidelines define the sustainability of outer space activities as the ***ability to maintain the conduct of space activities 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 present generations while preserving the outer space environment for future generations.

UN Doc. A/74/20
UN Doc. A/AC.105/C.1/L.366

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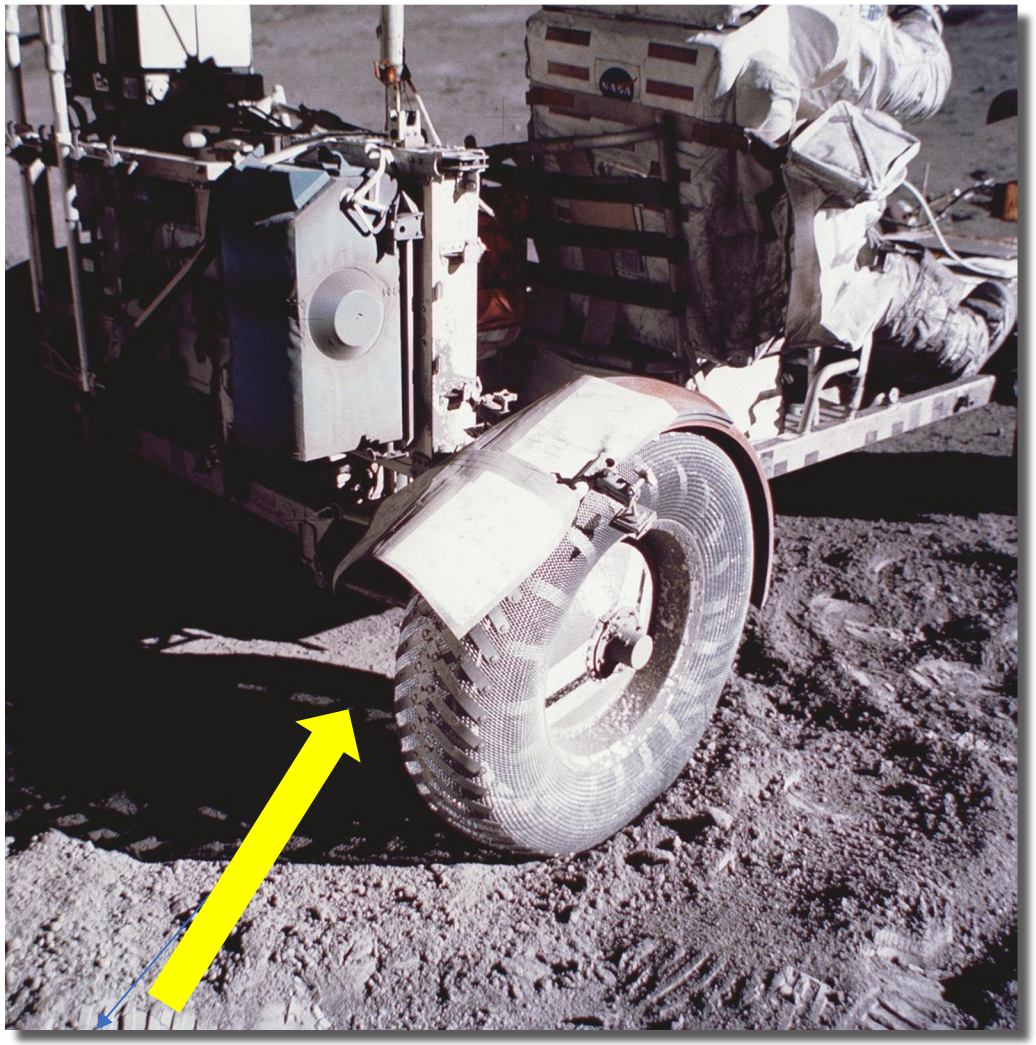

Stiff plasticized maps were taped together and fastened by clamps to patch a broken fender of the Apollo 17 Lunar Roving Vehicle (LRV).

"I think dust is probably one of our greatest inhibitors to a nominal operation on the Moon.
I think we can overcome other physiological or physical or mechanical problems except dust."

Gene Cernan

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Lunar regolith is the **layer of unconsolidated rocks, pebbles, and dust** that exists on the lunar bedrock. The particles are sharp and angular in nature, resulting in a much more abrasive material than their terrestrial counterparts

Regolith **is also adhesive**, both mechanically and electrostatically. **Mechanical adhesion** occurs because of the barbed shapes of the grains of dust. **Electrostatic adhesion** is caused by the charging of objects by various sources, such as solar wind plasma and photoionization.

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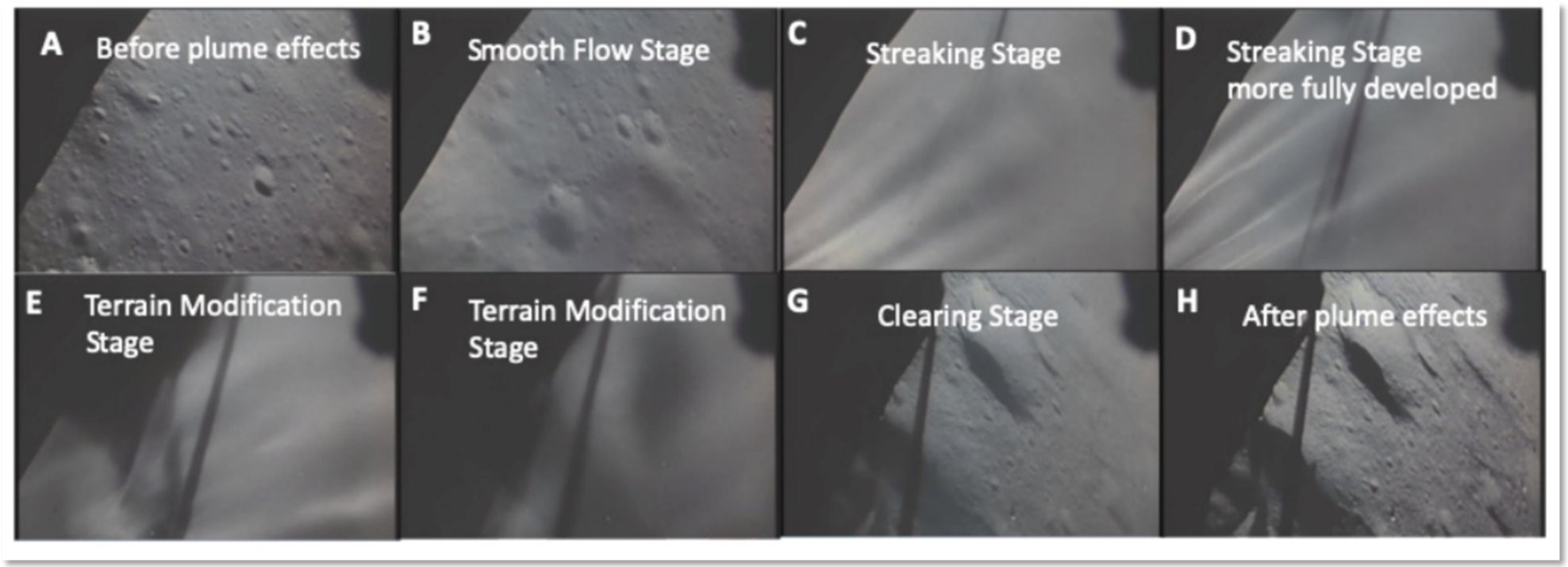

Stages of rocket exhaust ejecta beneath an Apollo Lunar Module. In smooth and streaking flow stages, ejecta is mainly in a sheet **1-3 degrees above horizontal**, although some individual streaks are at higher angles. In terrain modification stage much of the ejecta is lofted into higher angles **exceeding 15 degrees.**

Credit: Metzger, P., Smith, J., Lane, J., Phenomenology of soil erosion due to rocket exhaust on the Moon and the Mauna Kea lunar test site. Journal of Geophysical Research: Planets 116, no. E, 2011.

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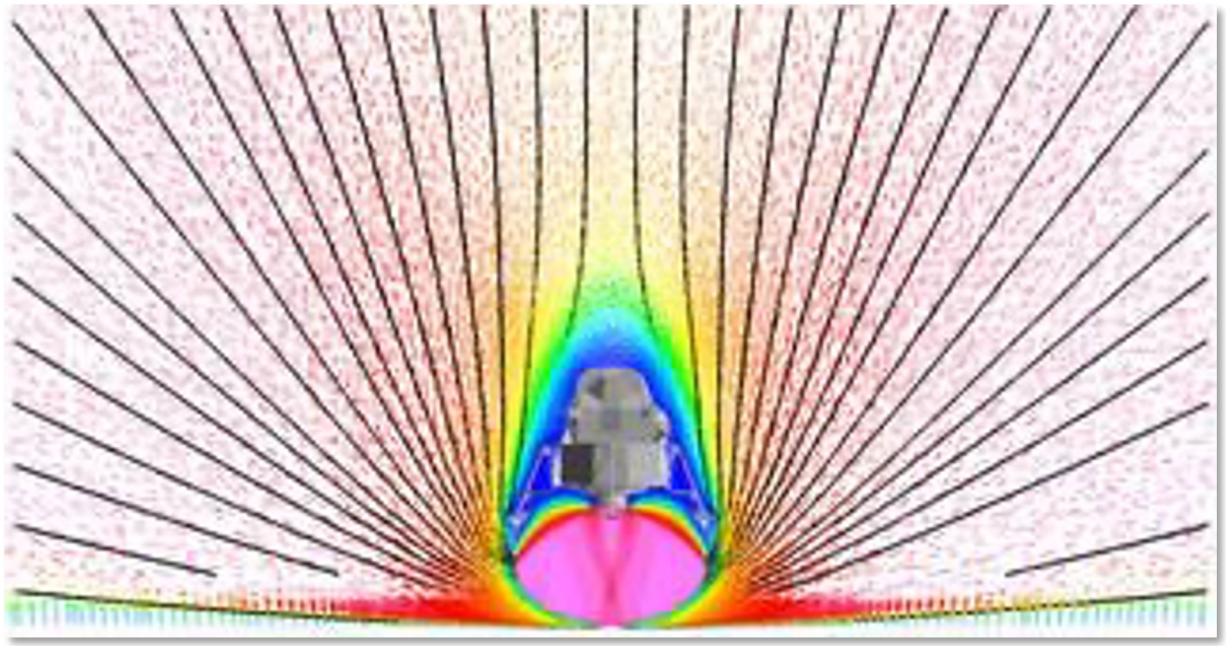

Apollo Lunar Module plume impingement at a distance of 5 m above the landing surface. Image shows plume gas velocity vectors colored by velocity magnitude (blue = low, magenta = high) as well as streamlines indicating the strong upward flow direction under vacuum conditions.
Credit: NASA

Rocks and larger particles may directly damage equipment.

Dust coating is a precursor to myriad other problems including:

- vision obscuration
- false instrument readings
- dust coating and contamination
- loss of traction
- clogging of mechanisms
- abrasion
- thermal control problems
- seal failures

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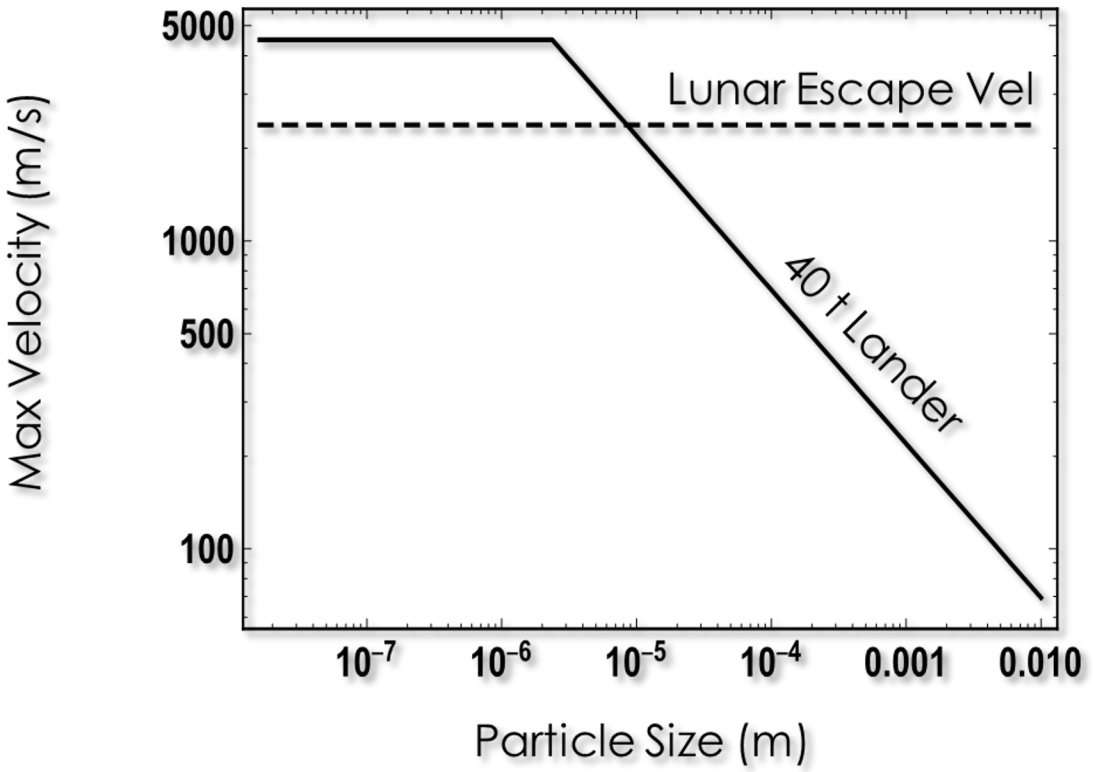

Model of maximum ejecta velocities as a function of lunar soil particle size.

This simulation indicates that particles up to 10 μm can be ejected completely off the Moon.

Credit: P. T. Metzger, Dust Transport and Its Effects Due to Landing Spacecraft, The Second NASA Engineering and Safety Center Workshop on the Impact of Lunar Dust on Human Exploration, 2020.

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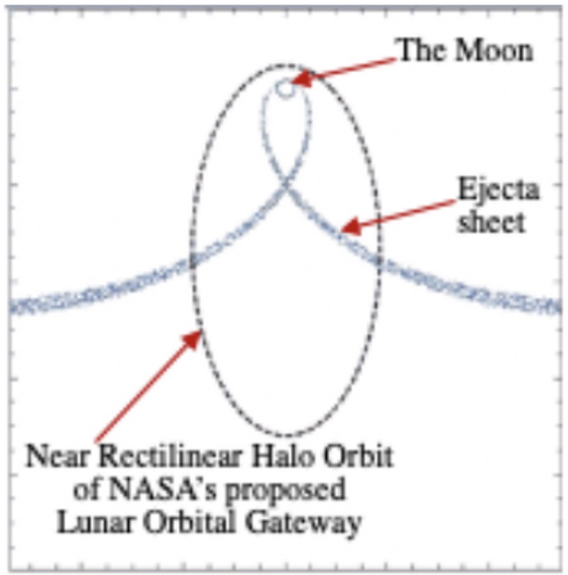

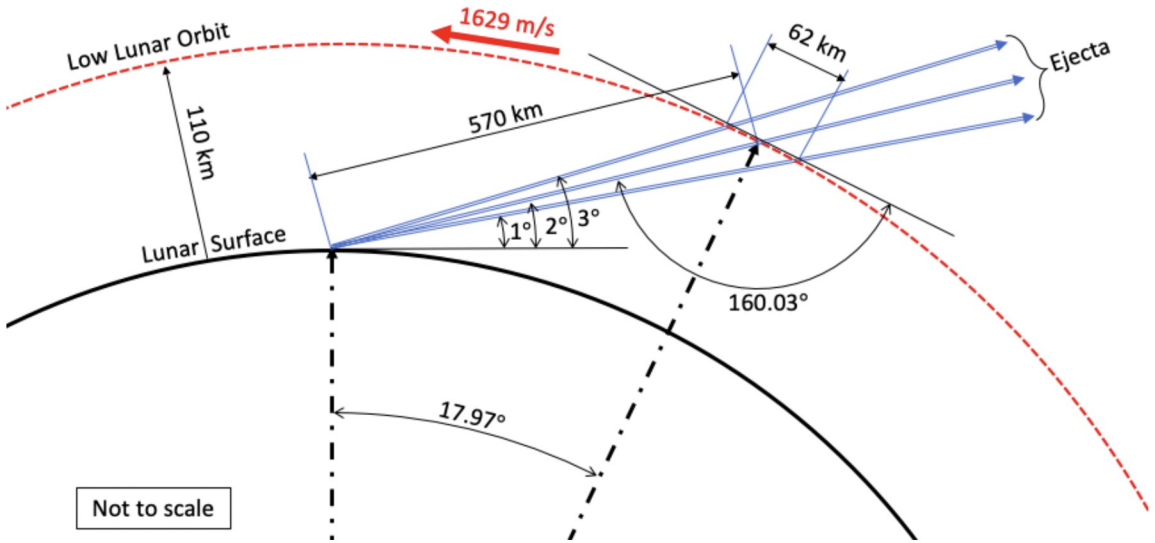

Left: Simulation of ejecta sheet traveling far from the Moon.
Right: Geometry of Ejecta Flux Impacting a Spacecraft in Low Lunar Orbit.

Credit: Philip T. Metzger and James G. Mantovani, The Damage to Lunar Orbiting Spacecraft Caused by the Ejecta of Lunar Landers, 17th Biennial International Conference on Engineering, Science, Construction, and Operations in Challenging Environments, 2021.

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Lunar activity is moving beyond short-duration, self-contained science missions. The potential for damage or mission failure caused by high-velocity ejecta will create an equal, perhaps greater, potential for conflict. A solution can be developed to forestall unnecessary tension or disputes.

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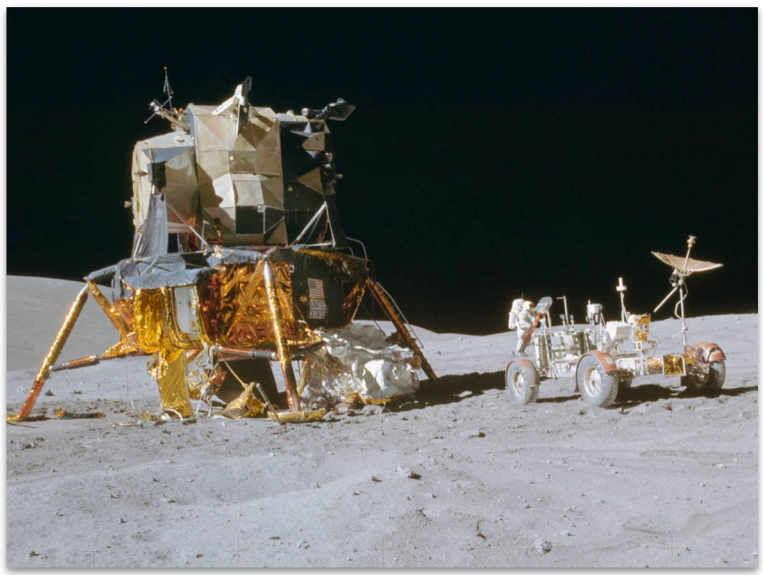

Creating protective zones is an excellent short term solution to reduce the possibility of conflict until we better understand the impacts of high velocity ejecta on the lunar surface and other celestial bodies.

For All Moonkind suggests that the first such zones can be implemented by the Committee on the Peaceful Uses of Outer Space to protect human cultural heritage on the Moon.

These can serve as a baseline for the discussion that must be had regarding how to ameliorate the effect of ejecta on future operational missions on the lunar surface and in lunar orbit.

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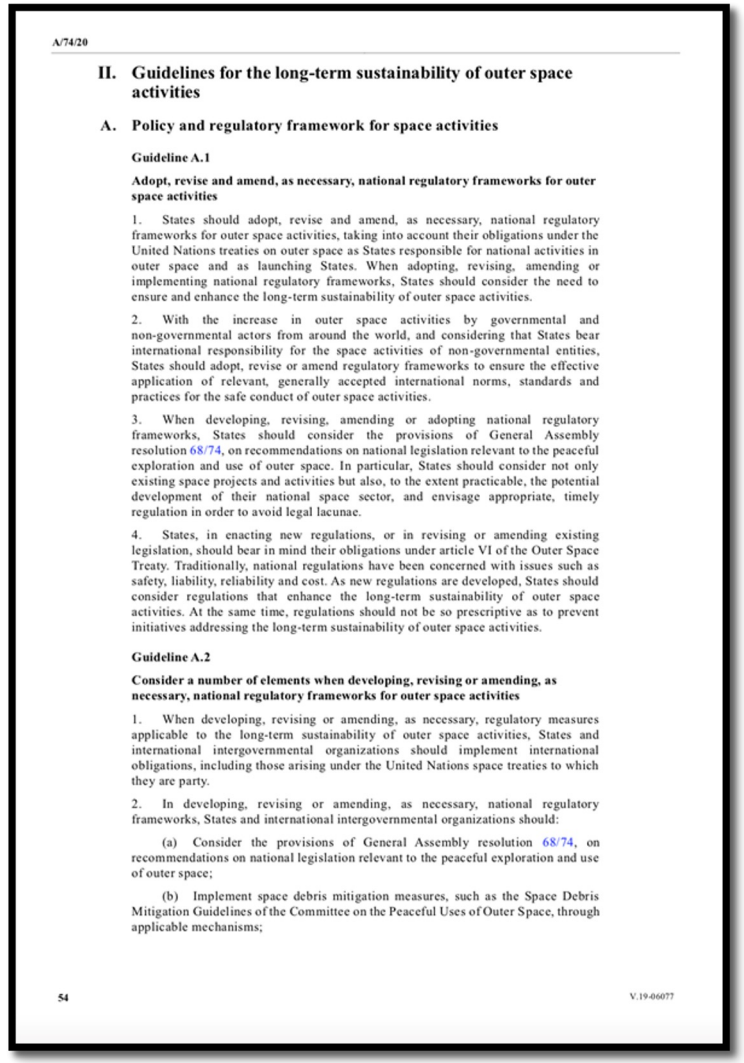
Nations engaged in – or whose nationals are engaged in – activities on the Moon have a **legal obligation** to **mitigate the potentially devastating effects** of lunar ejecta.

Beyond the responsibilities imposed by the Outer Space Treaty & the Liability Convention, the **LTS Guidelines** tell us that we, as the international community, must take steps to mitigate the risks associated with the conduct of outer space activities so that present benefits can be sustained, and future opportunities realized.



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II. Guidelines for the long-term sustainability of outer space activities

A. Policy and regulatory framework for space activities

Guideline A.1

Adopt, revise and amend, as necessary, national regulatory frameworks for outer space activities

1. States should adopt, revise and amend, as necessary, national regulatory frameworks for outer space activities, taking into account their obligations under the United Nations treaties on outer space as States responsible for national activities in outer space and as launching States. When adopting, revising, amending or implementing national regulatory frameworks, States should consider the need to ensure and enhance the long-term sustainability of outer space activities.

2. With the increase in outer space activities by governmental and non-governmental actors from around the world, and considering that States bear international responsibility for the space activities of non-governmental entities, States should adopt, revise or amend regulatory frameworks to ensure the effective application of relevant, generally accepted international norms, standards and practices for the safe conduct of outer space activities.

3. When developing, revising, amending or adopting national regulatory frameworks, States should consider the provisions of General Assembly resolution 68/74, on recommendations on national legislation relevant to the peaceful exploration and use of outer space. In particular, States should consider not only existing space projects and activities but also, to the extent practicable, the potential development of their national space sector, and envisage appropriate, timely regulation in order to avoid legal lacunae.

4. States, in enacting new regulations, or in revising or amending existing legislation, should bear in mind their obligations under article VI of the Outer Space Treaty. Traditionally, national regulations have been concerned with issues such as safety, liability, reliability and cost. As new regulations are developed, States should consider regulations that enhance the long-term sustainability of outer space activities. At the same time, regulations should not be so prescriptive as to prevent initiatives addressing the long-term sustainability of outer space activities.

Guideline A.2

Consider a number of elements when developing, revising or amending, as necessary, national regulatory frameworks for outer space activities

1. When developing, revising or amending, as necessary, regulatory measures applicable to the long-term sustainability of outer space activities, States and international intergovernmental organizations should implement international obligations, including those arising under the United Nations space treaties to which they are party.

2. In developing, revising or amending, as necessary, national regulatory frameworks, States and international intergovernmental organizations should:

(a) Consider the provisions of General Assembly resolution 68/74, on recommendations on national legislation relevant to the peaceful exploration and use of outer space;

(b) Implement space debris mitigation measures, such as the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space, through applicable mechanisms;

54

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Guideline A.1 provides that given the increase in space activities by both governmental and non-governmental actors from around the world, and considering that States bear international responsibility for the space activities of non-governmental entities, **States should adopt, revise, or amend regulatory frameworks** to ensure the effective application of relevant, generally accepted regulatory frameworks **to ensure the effective application of international norms, standards and practices for the safe conduct of outer space activities.**

Guideline A.3 provides that States should **encourage each entity** conducting space activities to **develop specific requirements** and procedures **to address the safety and reliability of outer space activities** under the entity's control and assess all risks to the long-term sustainability of outer space activities associated with the space activities conducted by the entity and **take steps to mitigate such risks to the extent feasible**.

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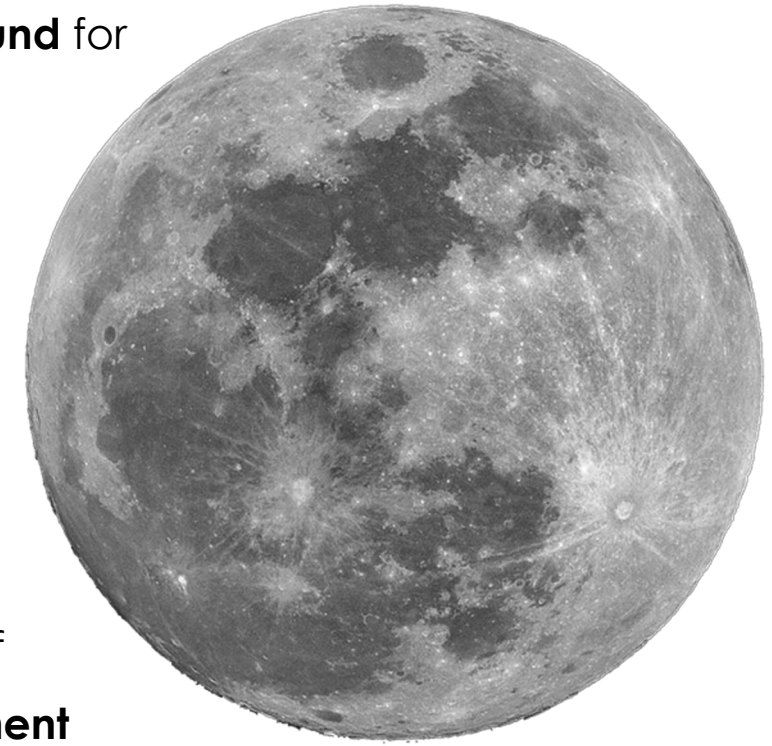
We look to the Moon as a **testing ground** for deeper exploration. And yet all of our efforts could be **fatally threatened** by the existence of the lunar dust, and the **destructive impact** lunar landings can have over the entire lunar surface, and even lunar orbit. We urge the Scientific and Technical Subcommittee to **reduce the threat** of conflict by considering the **establishment** of internationally recognized **protective zones** around our cultural heritage.



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Thank you

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