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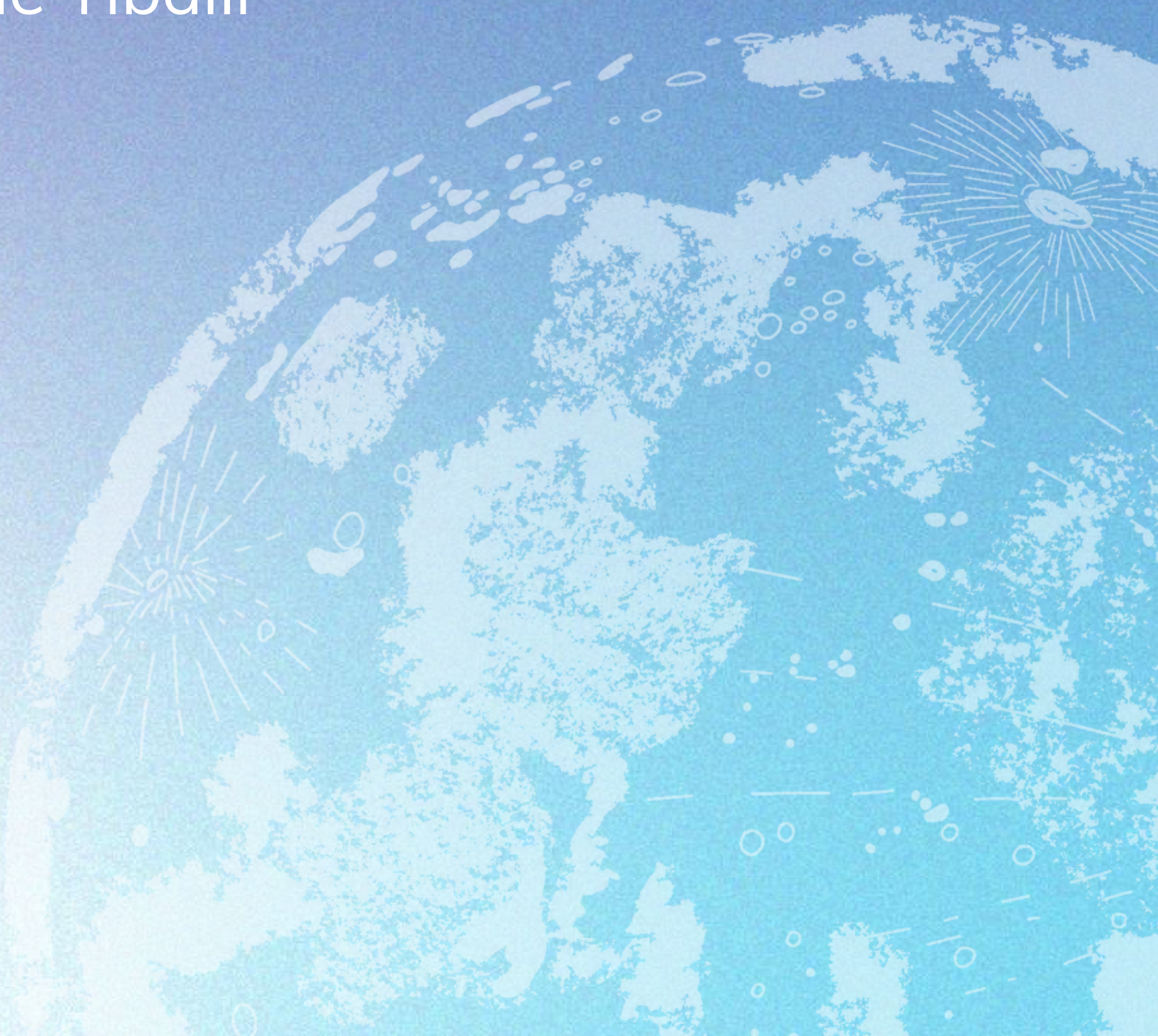
Lunar Operations Field Guide: Lunar Designated Areas

Christine Tiballi

2025



WELCOME TO THE MOON

NUCLEAR EDITION

With increasing mission cadence, the Moon is at heightened risk of morphing into a geopolitical pawn - sitting squarely in the crosshairs of a deeply contested geopolitical power struggle; one where national interests trump international consensus, and the Outer Space Treaty (OST) is at risk of losing its relevance to economic interests and threats of militarization.

Without clear norms around information sharing and operational frameworks that delineate safe conduct, we risk self-interest dictating activity across the domain. Sustainability, transparency, and cooperation may take a back seat to profit and national posturing, with even deeper threats of appropriation vs. collective stewardship.

This field guide aims to position transparency and cooperation at the heart of shared lunar development—where geopolitical, national, commercial, scientific, and public interests can align, work in tandem toward common goals, and deliver on the OST's promise of a shared resource for all mankind.

Recent developments around fission surface power have pushed these questions to the fore. While focus has been on timelines and capabilities, growing operational adjacencies, common areas of interest, and compounding risks require a different level of 'seeing'. This Field Guide's purpose is to illuminate and constructively mediate a path forward.

The Luna Operations Field Guide introduces a novel operating framework with sustainable guidelines for future lunar missions. Using elements of the Svalbard Treaty, Oceanic sovereignty, and resource management frameworks as terrestrial guides—specifically regarding open access and adaptable environmental protocols—a lunar equivalent is proposed.

Establishing norms around equal access and non-discrimination to lunar areas of heightened interest poses particularly complex challenges, especially around first mover advantages. Using adaptive environmental protocols, including evolving strategies based on data and discovery feedback loops, missions can operate in tandem while carrying out wider collective stewardship goals.

This Guide focuses on the development of lunar precautionary areas and harmonization areas where sensitive activities, proximity activities, or high contamination probability exists. It also proposes a lunar public purpose trust (PPT), comprising a broad spectrum of both national, commercial, and community stakeholders to manage stewardship and activity in areas deemed high-importance.

SITE SELECTION

WHY FOCUS ON THESE FOUR SITES?

Each of the selected sites holds inherent value due to resource availability, scientific potential, or ideal disposal parameters. As multiple missions are expected to converge on and leverage these areas, they represent ideal testing grounds for the three ring operating framework developed in this guide.

FARSIDE:

The lunar farside is a natural radio quiet area—Earth-based interference is completely blocked by the Moon's bulk. This makes it uniquely suited for ultra-sensitive radio astronomy arrays, but also complicates real-time communication and requires autonomous systems or relay satellites for mission support.

SHACKLETON CRATER:

With permanently shadowed regions reaching surface temperatures near -200°C, Shackleton harbors some of the Moon's richest confirmed water ice deposits. Its proximity to the lunar south pole also offers near-continuous line-of-sight to Earth for communications, making it a strategic hub for both resource extraction and long-duration habitation.

MARE IMBRIUM:

These basaltic plains contain high concentrations of ilmenite and other industrially relevant minerals, including trace helium-3 embedded in regolith from solar wind. Their stable topography and low slopes reduce landing risk and support large-scale mining or construction operations.

LUNAR EQUATOR (End-of-Life Graveyard Bands):

Equatorial impact corridors are selected for predictable targeting from most lunar orbits, minimizing fuel use during deorbit maneuvers. Concentrating debris in these bands reduces contamination risk to polar resources and science sites while simplifying future tracking or salvage efforts. However, this kind of operation comes with significant environmental risks and hazards.

WHO IS THIS FIELD GUIDE FOR?

This guide is intended for:

- Mission planners, operators, and policymakers working on the Moon's next chapter
- Engineers and safety officers who want clear rules (and fewer headaches)
- Space lawyers and diplomats navigating new kinds of territory
- Curious members of the public who want to understand how lunar operations actually work, beyond the headlines

It provides practical frameworks and reference material for coordinating operations, managing safety areas, and minimizing conflict as lunar activity increases.

Whether you're overseeing surface missions, drafting policy, or supporting international collaboration, this guide offers essential tools for safe and effective lunar engagement.

If you care about safe, smart, and fair activity on the Moon, this guide is for you.

- Each Site = quick facts + annotated visuals
- Colored Rings = Operational Areas (see legend below)
- Icon Flag = Hazards, resources & special rules
- Scenarios show real world coordination challenges

LEGEND:

THREE CONCENTRIC CIRCLES:

ORANGE (CORE OPERATIONS)

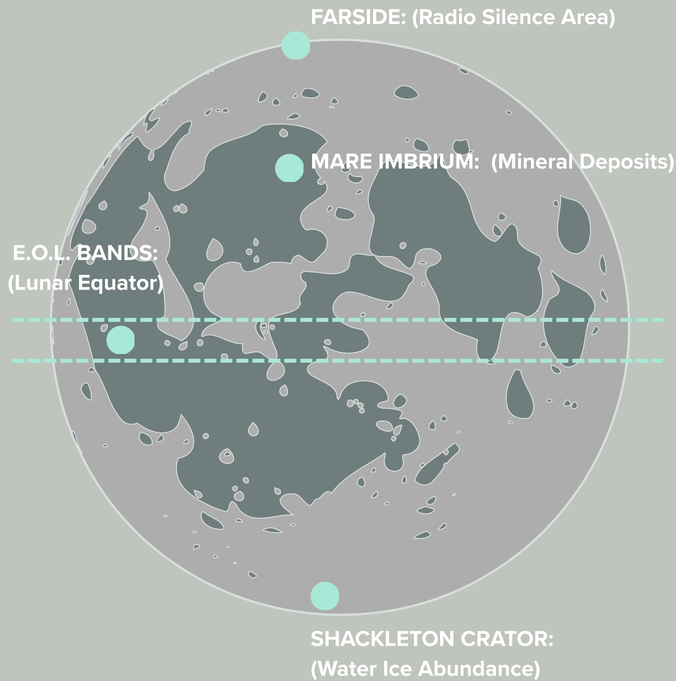
TEAL (HARMONIZATION AREAS)

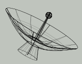
GRAY (COORDINATION BUFFER)

40-100kW NUCLEAR FISSION DEVICE

WATER-ICE ABUNDANCE IN LOCATION

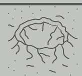
LUNAR HOT SPOTS



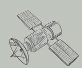


Farside:
Extreme radio silence; fundamental astrophysics; harsh terrain

Mare Imbrium:
Ancient lava plains; mineral resources; tricky footing



Shackleton Crater:
Permanent shadow; water ice deposits; high-value real estate



E.O.L. bands:
Orbital debris areas; safe decommissioning; legal gray area

THE 3-RING SAFETY SYSTEM

Precautionary areas, akin to buffer areas in environmental protection policies on Earth, facilitate diverse mission cooperation with minimal interference. Adaptive policies are crucial to ensuring harmonious interaction, particularly when commercial and scientific exploration, or life safety and specialized operations are concerned.

The proposed three ring safety system emphasizes the establishment of "harmonization areas," designed to structure adjacent or partially overlapping areas/activities where critical operations will occur. It has the benefit of facilitating the movement and interaction between different sectors and managing the transition from one activity type to another. Within these areas, flexible protocols, based on feedback loops and re-assessments will govern transitions and mitigate disputes, overlaps, or interference.

HOW IT WORKS

The **inner circle** comprises a three dimensional area with a temporal assignment, where activities, instrument deployments, or other core functions occur. In order to maintain safety and mission integrity, access is tightly controlled for any external parties (emergencies are the only anticipated exception). These boundaries require careful and methodically planned coordination and registration to ensure their integrity.

This innermost circle is defined by each mission as crucial for its operational success. Missions that operate in this area are also responsible for designating its boundaries and communicating transparently to ensure all stakeholders are well-informed.

The **middle circle** represents the activity mitigation areas, termed “harmonization areas”. These serve as transitional areas to handle the potential overlap of adjacent activities where noise, contamination, or safety challenges can be accommodated. Access here is limited to operators of adjacent missions but must be coordinated to prevent external contamination.

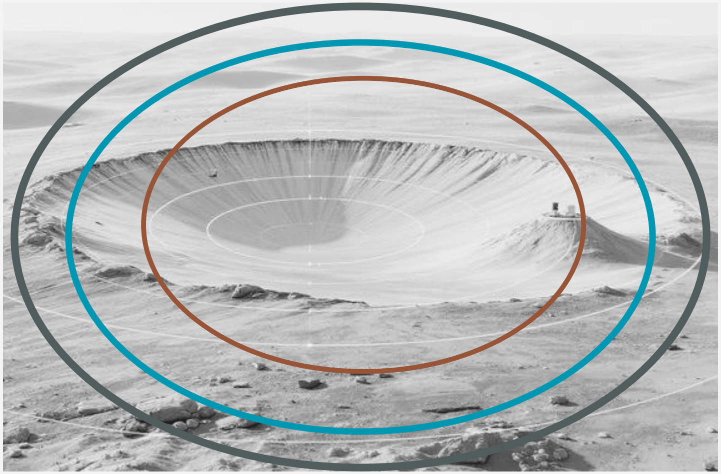
This middle area acts to protect the critical inner area from external interference. Access is granted only to operators with adjacent activities that necessitate coordination, like resource extraction or buffer area elements that support adjacent missions. Protocols will detail how activities need to be coordinated to prevent conflicts or disturbances.

The final **outermost circle** marks the full extent of the operational area designated by the operator, where less sensitive operations can be carried out or where critical operations can be staged. This area is flexible and less likely to impact operational goals, therefore access is broadly open, provided necessary permissions are obtained to prevent interference.

The outermost circle encapsulates the ideal broader area desired for conducting less vital operations. Interactions here encourage cooperation but remain contingent upon gaining necessary agreement when activities might affect one another.

In all three areas, transparency and planning are vital to maintaining the integrity of designated boundaries, to accommodate fluid risk-based change, and to rebalance dynamically with feedback from operations and discovery.

THE 3-RING SAFETY SYSTEM



- **INNERMOST CIRCLE*:* ORANGE** “Core Operations”
- **MIDDLE CIRCLE**: **TEAL** **“**Harmonization Area**”**
- **OUTERMOST CIRCLE**: **GRAY** “Coordination Buffer”

IN ACTION

Core Operations Area:

Only the operator may enter. Critical work happens here—think reactor maintenance or hazardous setup. Strictest safety limits apply.

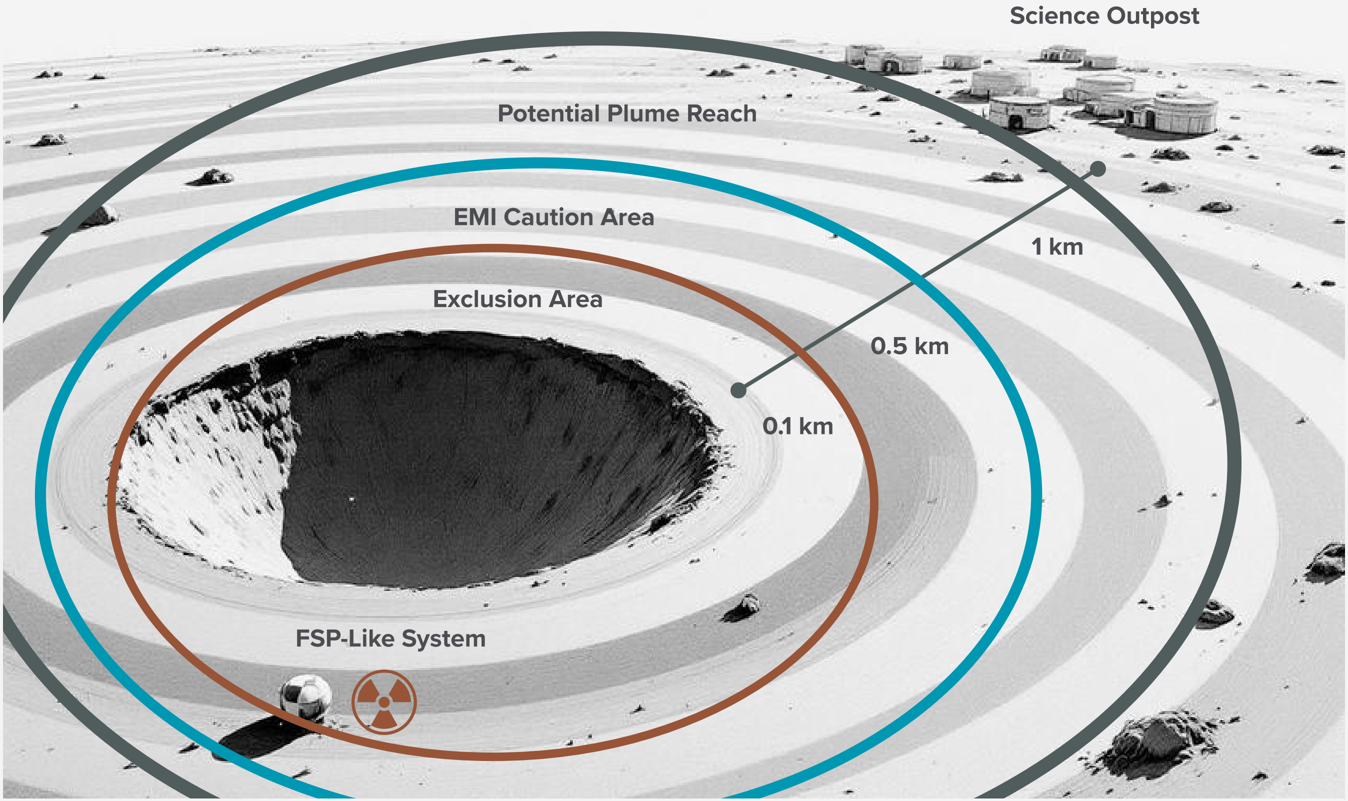
Harmonization Area:

Serves as a buffer and staging area. Other operators can cross— but only with advance coordination and under specific protocols.

Coordination Buffer Area:

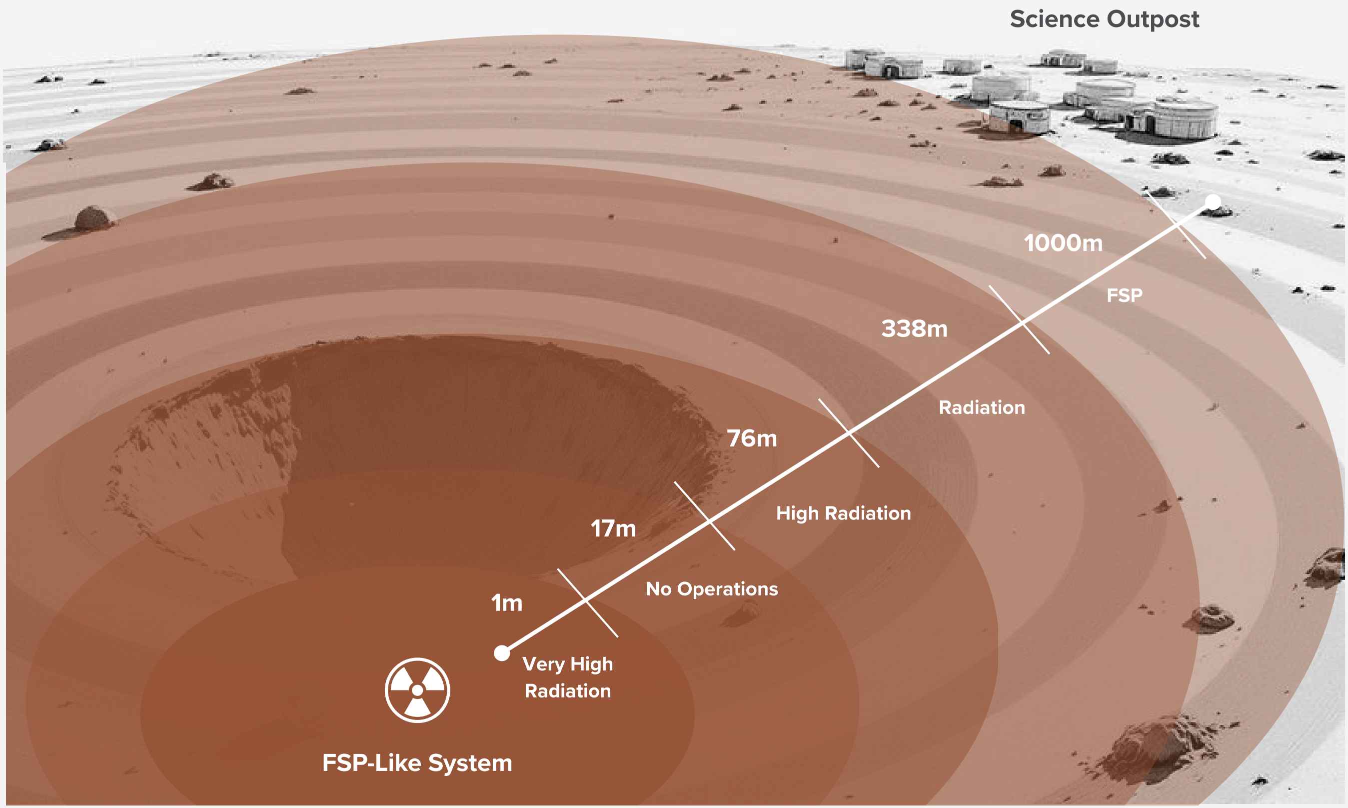
Outermost ring. Overlap is possible, but activities here shouldn’t affect core ops. Designed to keep everyone safe without stifling activity.

NUCLEAR POWER IN ACTION



- ***Core Operations Area:*** reactor maintenance only - no unshielded access
- ***Harmonization Area:*** breach allowed w/ prior notification; limit dwell time
- ***Coordination Buffer Area:*** minimal impact expected; routine monitoring only

SAMPLE EXPOSURE THRESHOLDS



Gilbert AQ: Radiation Fields and Safety Zones for Nuclear Systems on Planetary Surfaces. *Nuclear Science and Technology Open Research. 2025.*

FARSIDE

Quick Facts:

- **Location**: Lunar farside (Earth never visible)
- **Primary Value:** Pristine radio environment
- **Hazards:** Comms blackout, rough terrain

The farside is so quiet that even faint signals from the early universe can be detected, making it one of the most scientifically valuable spots off-Earth.

- **Radio Silence:** Ideal for deep space astronomy; zero terrestrial interference
- **Communications dead zone:** All operations require relay satellites or autonomous protocols
- **Terrain Challenge:** Steep walled craters and highlands make access tough
- **Low Traffic:** Few operators due to logistics; perfect for long-term science outposts

Governance Gray Zone:

No international treaty explicitly protects lunar radio silence areas - operators must coordinate voluntarily or risk mutual interference.

Scenario:

In 2034 ***Operator C*** establishes a radio observatory on the farside. All equipment was delivered by autonomous rover - no direct communications with Earth during setup. now, a critical component needs replacement. Since human or robotic maintenance would disrupt the observatory's 'radio silence' uptime, how should operators coordinate supply runs? See scenario on pp. 17 - 18

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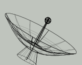
Scenario 01:

In 2034 ***Operator A*** establishes a radio observatory on the farside. All equipment was delivered by autonomous rover - no direct communications with Earth during setup. Now, a critical component needs replacement. since human or robotic maintenance would disrupt the observatory's 'radio silence' uptime. How should operators coordinate supply runs?

Priming Questions:

- *Do you schedule all maintenance during planned downtime windows?*
- *Can multiple operators batch deliveries to minimize interference?*
- *Who decides when it's safe to cross into the harmonization area?*



Scenario 01:

Potential Resolution:

- Operators agree on a shared maintenance calendar, designating specific “quiet windows” and “service windows”
- All supply runs or repairs are scheduled during pre-arranged downtime blocks, minimizing science disruption
- Harmonization area protocols require any operator crossing to notify all others at least two weeks in advance; Core ops area entry is only allowed during full system shutdowns
- An independent third party (or automated scheduling platform) logs all planned crossings for transparency

Result:

Observatory uptime is maximized, logistics are predictable, and everyone knows when it's safe to operate without causing interference.

MARE IMBRIUM (VOLCANIC PLAINS)

Quick Facts:

- **Location**: Northwest lunar nearside
- **Primary Value:** Basaltic minerals, smooth landing areas
- **Hazards:** Dust storms (electrostatic), hidden lava tubes

Mare regions cover 16% of the Moon's surface but hold most of its accessible metals, making them the lunar equivalent of the Klondike

- **Ancient lava fields:** Formed by massive volcanic eruptions billions of years ago; regolith rich in rare minerals
- **Prime Real Estate:** Smooth surface = ideal for landers, rovers, and mining ops
- **Hidden Hazards:** Subsurface lava tubes can collapse without warning; dust is clingy and abrasive
- **Resource Rush:** Multiple operators eyeing extraction rights; overlapping claims likely

Governance Gray Zone:

Current treaties don't define who pays when one operator's activities physically impact another - leaving everyone exposed to operational risk and legal ambiguity.

Scenario:

Operator B begins mining for helium-3 in Mare Imbrium, processing huge volumes of regolith. Soon after, **Operator C** sets up an adjacent claim, whose harmonization area overlaps with **B's** coordination buffer area. How are these overlaps handled? See scenario on pp. 21 - 22

Scenario 02:

Operator B begins mining for helium-3 in Mare Imbrium, processing huge volumes of regolith. Soon after, **Operator C** sets up an adjacent claim, whose harmonization area overlaps with **B's** coordination buffer area. How are these overlaps handled?

Priming Questions:

- *How do they coordinate massive material transport so dust and vibration don't disrupt each other's operations?*
- *il both need to run heavy equipment 24/7 to stay viable, who gets priority during overlapping 'core ops' windows?*
- *Can they agree on shared infrastructure (roads, power) within the harmonization area, or does competition make that impossible?*

Scenario 02:

Potential Resolution:

- Both operators are required to submit detailed operational schedules and dust mitigation plans at least 30 days in advance
- Overlapping harmonization areas trigger a joint review:
  - Operators negotiate alternating "core ops" windows (e.g., **B** runs full-scale mining while **C** pauses, then swap)
  - Shared infrastructure (like dust barriers or haul roads) is discussed; costs and maintenance split proportionally
- Real-time environmental monitoring is set up at area boundaries: if dust/plume levels exceed agreed thresholds, operations must pause until safe
- Any disputes over contamination or interference are mediated by a neutral third party; all incidents logged for transparency

Result:

Both can extract resources efficiently without ruining each other's gear or safety margins. Operational friction becomes manageable instead of catastrophic.

SHAKELTON CRATER

Quick Facts:

- **Location**: Lunar south pole
- **Primary Value:** Water-ice deposits
- **Hazards:** Permanent shadow, extreme temperatures

Shackleton crater's floor hasn't seen sunlight in over two billion years, temperatures hover near -200°c, making it one of the coldest places in the solar system and a natural deep-freeze for water ice deposits

- **Resource Hotspot:** Abundant water-ice in shadowed regions
- **Crowded Real Estate:** High interest from multiple nations/companies/science
- **Unique Hazards:** Sunlight never reaches the crater floor; equipment must handle deep freeze
- **Operational Challenge:** Overlapping safety areas require tight coordination

Governance Gray Zone:

Permanent shadow means solar power is tricky, so nuclear installations are likely - but there's no international standard for minimum safety distances between rival reactors or habitats in space. One operator's safety area could block another from accessing critical resources, with no legal recourse except negotiation (or escalation).

Scenario:

Operator D stages an RPS device near a crater's edge to power operations for water-ice discovery and sample extraction. **Operator E** wants to reposition a rover on the crater edge, but power demands make crossing through the Harmonization Area more feasible. What happens? See scenario on pp. 25 - 26

Scenario 03:

Operator D stages an FSP device near a crater's edge to power operations for water-ice discovery and sample extraction. ***Operator E*** wants to reposition a rover on the crater edge, but power demands make crossing through the Harmonization Area more feasible. What happens?

Priming Questions:

- *If **Operator D**'s FSP exclusion area blocks the most direct route to water ice, how can **Operator E** safely reposition their rover for extraction work?*
- *What protocols decide who gets priority access to overlapping harmonization areas: first come, resource value, or negotiated time-sharing?*
- *If both operators need to run power-hungry equipment at the same time, how do they coordinate without risking safety or operational delays?*
- *Who mediates when two operators can't agree on a crossing schedule or safety buffer?*

Scenario 03:

Potential Resolution:

- **Operator E** submits a formal request to cross through the harmonization area at least 30 days in advance, detailing timing, route, and duration
- **Operator D** reviews the request for conflicts with critical operations or safety protocols (e.g., maintenance windows, radiation spikes)
- Both operators coordinate to schedule the crossing during a low-risk window - possibly pausing sensitive work or boosting monitoring during transit
- Real-time comms are established between both teams during the crossing; emergency stop protocols are agreed upon in advance

Result:

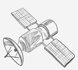
Operator E gets efficient access without jeopardizing safety or disrupting **Operator D's** core operations. Trust and transparency are reinforced for future coordination.

E.O.L. BANDS (LUNAR EQUATOR)

Quick Facts:

- **Location**: Two equatorial surface bands identified as safe decommissioning areas
- **Primary Value:** Controlled disposal of defunct assets
- **Hazards:** Debris field expansion, possible contamination

Most lunar orbits (especially low-energy, stable ones) are inclined, but nearly all pass over the equator twice per orbit, because the Moon isn't tilted much and has no thick atmosphere to "drag" things down



- **Designated Decommissioning Sites:** Most lunar assets can be deorbited here with minimal burn/maneuvers
- **Out of Sight, Out of Mind:** Graveyard bands are far from high-value sites but not immune to future interference or salvage attempts
- **Collision Hazards:** As more satellites pile up, risk of chain-reaction debris increases
- **No Maintenance:** Once in the band, objects are abandoned; monitoring is rare

Governance Gray Zone:

There's no binding international rule requiring operators to use these graveyard bands - or to track what they leave behind. If debris from one nation damages another's future mission, liability is murky at best. Salvage rights are also undefined: Is abandoned hardware fair game or protected property?

Scenario:

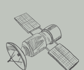
Operator F plans to deorbit a defunct satellite into the southern graveyard band. Under the 3-ring system, a temporal exclusion area is established around the projected impact site. See scenario on pp. 29 - 30

Scenario 04:

Operator F plans to deorbit a defunct satellite into the southern graveyard band. Under the 3-ring system, a temporal exclusion area is established around the projected impact site.

Priming Questions:

- *Before deorbiting a defunct asset into a graveyard band, how much advance notice must **Operator F** give to nearby surface missions?*
- *What happens if another operator needs to traverse the harmonization area during the high-risk impact window: can crossings be delayed or rerouted?*
- *Who is responsible for mapping and communicating new debris fields after each impact event?*
- *If future missions are damaged by legacy debris in these bands, is there a process for assigning liability or coordinating cleanup?*



Scenario 04:

Potential Resolution:

- **Core ops zone:** Only **Operator F's** team allowed during descent and immediate aftermath (debris risk, plume hazards)
- **Harmonization area:** Adjacent operators must coordinate if they need to cross for surface work or rover traverses; access limited during high-risk window
- **Coordination buffer area**: Nearby activities discouraged but not banned, operators are notified of timing and trajectory

Result:

A week later, **Operator G** wants to send a rover through the harmonization area to reach a distant science target. Both teams negotiate a safe window after debris settles, minimizing risk and downtime.

GOVERNING THE LUNAR COMMONS

As lunar activity increases, clear rules and trusted mediators are as critical as engineering or science. The 3-ring safety system is only as strong as the governance behind it: without shared oversight, even perfect protocols can fall apart in a crisis.

That's where collaborative frameworks like Public Purpose Trusts (PPTs) come in. By anchoring stewardship in law, not just goodwill, a lunar consortium can:

- Monitor safety areas in real time (think: digital twins tracking who's where, when)
- Mediate disputes when harmonization areas overlap or scenarios get complex
- Adapt policies as new tech, discoveries, or stakeholders emerge
- Maintain transparent records of agreements and area status
- Ensure all voices, from space agencies to new entrants and marginalized groups, have a seat at the table
- Safeguards resources for both current missions and future generations
- Anchors decision-making in law, not just handshake deals

A PPT would work in tandem with existing UN bodies, such as ATLAC, to ensure alignment with international space norms and policy. This partnership strengthens legitimacy and fosters a unified approach to lunar governance.

PPTs work because they blend legal accountability with adaptive management. Terrestrial analogues like the Great Barrier Reef Authority show how multi-stakeholder governance can protect resources while enabling sustainable use. On the Moon, this means no single actor dominates access or sets rules unilaterally.

A lunar consortium built on PPT principles would act as:

- **Custodian:** safeguarding resources for current and future missions
- **Mediator:** resolving conflicts over exclusion areas, resource claims, or operational timing
- **Arbiter of transparency:** maintaining public records of agreements and area status
- **Platform for innovation:** updating protocols as science and tech evolve

The 3-ring framework provides structure; public purpose trusts provide legitimacy and teeth; together, they turn "best practices" into actual practice, making sure lunar development is fair, resilient, and future-proof.

Why this matters:
For a global commons like the Moon, with no single owner or enforcer, a PPT consortium offers practical legitimacy. It turns voluntary cooperation into binding practice, reduces conflict risk, and makes sure no one actor can dominate or exploit shared resources unchecked.

CONCLUSION

Tools for Real-Time Monitoring and Management

In the evolving landscape of lunar operations, digital technologies will play a vital role in ensuring the safety and sustainability of all activities. Embracing innovative tools like digital twins and predictive risk models becomes fundamental to informed, data-driven decision making, providing the capability of near real-time monitoring and operational scenario modeling to predict and mitigate risk.

By cataloging and actively revising surface features, in addition to recording both successful and unsuccessful landing sites as references, deeper insights into proximity conditions and risks, and limitations of communication and power will unfold.

Deployment of Digital Technologies

Allowing stakeholders to visualize potential scenarios across multiple dimensions, digital twins facilitate strategic planning by predicting risks and preemptively identifying safety or contamination issues before they play out on the ground. When combined with digital twins, predictive risk models leverage historical data, machine learning, and existing operational metrics to anticipate challenging scenarios across the dynamic lunar operational environment. With foresight into potential breaches, organizations are enabled to recalibrate strategies and maintain resilient operations.

In terrestrial applications, digital twins and risk modeling have been deployed successfully around urban development. Integrating climate risk factors, they not only provide actionable insights but mitigation opportunities across highly interconnected systems and operations.

A critical application for the lunar environment would intuitively be found in breach notifications, adjacent boundary changes, or capacity assessments. Integrated communication and data sharing protocols ensure that any issues are less impactful on neighboring activities or on resource management. Including designated buffer areas around all activities forms another level of mitigation and risk reduction, ensuring all stakeholders have the appropriate tools to manage unintended consequences and foster a cooperative environment.

As lunar operations scale, these digital tools are most powerful when embedded within collaborative frameworks like the lunar PPT, ensuring data isn't just collected, but acted on transparently and equitably.

The moon is our first real testbed for managing a global commons beyond earth; how we monitor, share, and respond here will set precedent for every world that follows.

GLOSSARY & SYMBOLS

- **action team on lunar activities consultation (atlac):** a UN-affiliated group focused on coordinating international policy
- **coordination buffer area:** outermost ring; overlap possible but discouraged
- **core ops area**: innermost safety ring; only operator allowed; highest risk
- **deorbit window**: planned time/trajectory for sending a spacecraft to its final crash site
- **electromagnetic interference (EMI)**: disruption of electronic systems caused by unwanted electromagnetic signals from nearby devices or equipment
- **exclusion area:** area around hazardous site where access is restricted or temporal for safety reasons
- **fission surface power (FSP)**: compact nuclear power source for lunar ops.
- **graveyard band**: designated equatorial crash area for dead satellites/probes
- **harmonization area**: buffer area; crossings allowed with advance coordination
- **outer space treaty (OST)**: 1967 treaty banning national ownership of the Moon and weapons in space; sets broad rules but leaves resource rights and safety areas vague
- **permanent shadow region (PSR)**: crater areas never see sunlight; prime ice real estate

- **public purpose trust (PPT):** a legal structure that manages resources or responsibilities for the collective benefit of all stakeholders, prioritizing stewardship over profit or exclusive control
- **radio silence area** farside regions shielded from Earth's radio noise - astronomy heaven
- **regolith**: lunar soil, sharp as glass and sticks to everything

THREE CONCENTRIC CIRCLES:

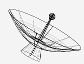
ORANGE (CORE OPERATIONS)

TEAL (HARMONIZATION AREAS)

GRAY (COORDINATION BUFFER)

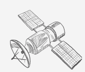
40-100kW NUCLEAR FISSION DEVICE

WATER-ICE ABUNDANCE IN LOCATION



RADIO QUIET CRITICAL RADIO ASTRONOMY AREAS

MARE MINERAL ABUNDANCE MINING PROSPECTS



E.O.L. BANDS DEORBITING AREAS

SHACKLETON CRATER PERMANENT SHADOW, WATER ICE

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IMAGES

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How to Stand up a Lunar Public Purpose Trust (PPT)

1. **Establish the Trust**
   - Define the trust's mandate: stewardship of lunar resources, safety area management, conflict resolution, transparency
   - Draft founding charter with clear mission, legal basis (international law/UN COPUOS alignment), and scope

2. **Membership & Governance**
   - Multi-sector board: national agencies, commercial operators, scientific orgs, civil society reps
   - Observer status for new entrants and marginalized voices
   - Rotating leadership or co-chair model to prevent dominance by any one actor

3. **Decision-Making Process**
   - Consensus-driven where possible; fallback voting mechanism for deadlocks
   - Standing committees for technical standards, dispute mediation, and environmental monitoring

4. **Operational Tools**
   - Digital twin platform for real-time mapping and monitoring of all lunar activities and 3-ring safety areas
   - Integration with the Lunar Ledger project: a global, tamper-evident database cataloging lunar objects and activities
   - Public registry of claims, incidents, and safety notifications

   - Public registry (linked to the ledger) for transparent logging of agreements, safety notifications, and area status updates
   - Standardized protocols for requesting access or crossings within harmonization areas, ensuring predictable coordination
   - Automated breach alerts and capacity assessments to support rapid response and adaptive management
   - Use the Ledger as a shared foundation for trust, cooperation, and real-time situational awareness among all stakeholders

5. **Enforcement & Accountability**
   - Binding dispute resolution process (arbitration panel or third-party mediator)
   - Transparent reporting requirements; regular audits of compliance
   - Sanctions or loss of access privileges for repeated non-compliance

6. **Adaptability & Review**
   - Scheduled policy reviews to incorporate new tech/science/stakeholders
   - Open channels for feedback from all sectors, including public comment periods