Minimum Evidence Before Lunar Commitment

Governing Surface Hardening Under Persistent Subsurface Ignorance

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1. The Core Problem: Premature Anchoring

Lunar development is often misclassified as a purely architectural or engineering challenge. A lunar architecture can be internally coherent and technically plausible while remaining inadmissible if it commits to a site before subsurface uncertainty is resolved at the scale of the commitment being authorized. At the lunar south pole, volatile-bearing materials are inferred through indirect evidence, including hydrogen indications, thermal stability, and radar response. These signals justify exploration. They do not by themselves justify infrastructure commitment.

The Path to Irreversibility

Commitment does not begin with permanent construction. It forms earlier through a sequence of actions that make future alternatives harder to preserve:

1. **Site privileging:** a location becomes favored through repeated access, mission planning, partner coordination, or reference architecture.
2. **Surface hardening:** landing pad preparation, berm construction, grading, or repeated traffic begins to alter the site and concentrate future operations.
3. **Geometry fixation:** corridors, power placement, communications support, or logistics pathways begin to define where future assets can operate.

Once these actions occur, they shape where future systems go and may disturb the evidence needed to verify the original resource assumption. The burden of evidence must rise with the burden of the action.

2. The Three-Layer Evaluation Framework

To prevent lunar projects from becoming committed before they are admissible, progress should be evaluated across three distinct layers.

1. **Architecture Readiness:** are the systems, including mobility, power, logistics, communications, and resource support, coherent?
2. **Construction Readiness:** can the system physically function at the specific site, given slopes, regolith behavior, illumination, thermal conditions, and access constraints?
3. **Commitment Readiness:** should this path-dependent action be allowed to proceed given what remains unresolved?

Architecture and construction readiness often outpace admissibility. The danger is that a concept becomes persuasive before the evidence has earned the right to anchor it.

3. Surface Commitment Classes

Eight classes of action should be treated as commitment-bearing. These are commitment thresholds where optionality begins to decay and future alternatives become harder to preserve.

- **SC-1 to SC-3: Spatial Anchoring**: Site hardening, landing pad preparation, and berm or blast protection begin to fix the geometry of future logistics.
- **SC-4 and SC-8**: Physical Disturbance: Excavation, trenching, and subsurface access are both epistemic and structural. They provide data while potentially altering the environment being evaluated.
- **SC-5:** Corridor Establishment: Repeated or designed routing turns movement choice into a fixed pattern.
- **SC-6 and SC-7**: Systemic Lock-In: Regolith processing dependency and fixed infrastructure placement allow resource assumptions, power, communications, and support systems to shape future architecture.

4. Primary Admissibility Tests

Before authorizing any commitment-bearing action, the project must satisfy two primary tests. These tests do not exhaust the framework. They are the minimum gates that determine whether unresolved uncertainty still governs the proposed commitment.

4.1. The Ignorance Dominance Condition

A commitment is inadmissible if multiple materially plausible subsurface states remain consistent with current evidence but would produce materially different outcomes.

The question is: If the subsurface reality differed within the range still permitted by current evidence, would we change this decision? If yes, uncertainty is decision-dominant, and commitment must defer to measurement.

4.2. The Architecture Independence Test

Can the proposed action remain genuinely exploratory, or does it induce architecture formation?

If a rover traverse, drilling event, excavation, or sampling campaign requires fixed power, repeated logistics, or standardized access, it is no longer only exploration. It is a commitment-bearing act that requires a higher standard of evidence.

4.3. Supporting Evaluation Checks

Depending on the proposed action, the screen may also evaluate scale match, disturbance consequence, optionality preservation, reversibility burden, support-system coupling, and commitment integrity. These checks determine whether the action remains bounded investigation or begins to create path-dependent commitment.

4.4. Commitment Threshold Criteria

A lunar surface commitment may proceed only when:

1. Evidence converges across relevant sensing modalities.
2. The evidence is resolved at the scale of the proposed action.
3. Plausible subsurface states no longer imply materially different infrastructure decisions.
4. Verification does not create more irreversibility than it resolves.
5. Site, access, support, and resource assumptions remain separable.
6. Refusal, re-siting, or re-sequencing remains credible.
7. The action is robust across remaining plausible states.
8. Commitment integrity can be maintained after the action begins.

If these conditions are not met, the correct determination is DEFER or REFUSE, not quiet preparation for commitment.

5. Decision Gate Outcomes

Every proposed surface action should resolve to one of three determinations:

1. **Proceed-Compatible:** the proposed step remains defensible within defined bounds.
2. **Defer-Indicated:** the project must reduce decision-dominant uncertainty while preserving optionality.
3. **Refusal-Required:** the proposed action creates exposure that the evidence basis cannot justify.

6. Commitment Integrity

Admissibility governs whether a commitment may begin. Integrity governs whether the authority to continue, constrain, or stop remains real as the commitment hardens. A commitment that is admissible at one stage may lose integrity if new evidence changes the plausible subsurface state space, if support systems exceed their original bounds, or if site, corridor, power, or ISRU dependencies accumulate faster than understanding.

Integrity review asks whether the commitment should be maintained, constrained, re-evaluated, or terminated. Its purpose is to prevent momentum, dependency, or prior signaling from replacing decision authority.

7. Case Study: Volatile Signal to Infrastructure Anchor

1. **Question:** Should a volatile signal at the lunar south pole govern the placement of a primary ISRU and infrastructure anchor?
2. **Current Signal:** The evidence supports exploration interest through hydrogen indications and related volatile-preservation context.
3. **Remaining Ambiguity:** The signal remains consistent with several materially different realities, including an architecture-grade deposit, a patchy operational resource, or diffuse and inaccessible volatile-bearing material.
4. **Determination:** DEFER. Current evidence justifies continued measurement and bounded verification. It does not yet justify irreversible site hardening or dependency of an architecture on an unverified deposit.
5. **What Would Change the Determination:** A future PROCEED determination would require evidence showing that the proposed infrastructure anchor remains robust across the remaining plausible subsurface states. This could include convergence across sensing modalities, scale-matched local verification, bounded disturbance results, acceptable regolith mechanics, demonstrated resource accessibility, and a support architecture that remains viable if the deposit is less continuous or less extractable than expected.

Until then, the admissible path is bounded evidence acquisition that preserves the ability to re-site, re-sequence, or refuse.