Signal-to-Commitment Consideration Map

Lunar Vertical

This document is the Section 1–5 consideration map for the lunar vertical in the From Signal to Commitment series. It expands the compressed poster logic into a fuller decision map across Detectability Limits, Ambiguity Persistence, Environmental Response, Architecture Under Constraint, and Commitment Thresholds. The poster is the public visual layer. This document is the structured consideration layer behind the poster. It is not a mission design, site-selection study, or ISRU architecture. It is a decision-governance map showing where evidence remains exploratory, where ambiguity persists, where action changes the system, where architecture begins forming dependency, and where commitment becomes admissible, deferred, or refused.

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1. The Lunar Vertical

1.1. Vertical definition

Lunar governs the decision boundary at which orbital and surface prospecting harden into site access, surface disturbance, corridor formation, resource dependence, and fixed infrastructure commitment under sparse evidence and high irreversibility.

This is not only a planetary science problem. It is a disturbance-constrained exploration problem in which indirect sensing remains non-unique, verification requires surface or subsurface disturbance, and early acts can create enduring path dependence across mobility, power, logistics, and governance.

1.2. Decision class

Pre-commitment lunar admissibility under subsurface ambiguity, surface–subsurface coupling, infrastructure sequencing, and irreversible first-access effects.

1.3. Core commitment under review

Whether a candidate lunar site, corridor, resource hypothesis, or surface architecture should be allowed to proceed from reversible prospecting into site hardening, excavation, mobility corridors, regolith dependence, fixed infrastructure, and long-horizon operational commitment.

1.4. Irreversibility lens

This map treats lunar exploration as a sequence of thresholds, not a linear progression from data to construction.

The governing issue is not whether an action is scientifically useful or technically feasible. The issue is whether the action materially reduces the ability to refuse, defer, re-site, or re-sequence later.

A lunar action becomes commitment-bearing when it begins to make one site, one corridor, one resource interpretation, or one support architecture easier to continue than to abandon.

This is the bridge from signal to decision.

2. Master Map

2.1. Detectability Limits

2.1.1 Section purpose

This section defines what can be known about the lunar surface and shallow subsurface before disturbance or fixed surface commitment begins.

2.1.2 Core question

What can orbital and surface evidence resolve about terrain, regolith, volatiles, and shallow subsurface structure before excavation, drilling, or infrastructure placement occur?

2.1.3 Key variables

- volatile presence and form
- regolith thickness and layering
- buried blockiness and mechanical heterogeneity
- slope, roughness, and landing hazard profile

- thermal regime and illumination conditions
- bearing strength and trafficability
- shallow voids or structurally weak zones
- local topography relevant to line-of-sight and power access
- surface-access geometry to candidate targets
- concentration versus distribution of resources

2.1.4 Observable variables

- neutron signatures and hydrogen proxies
- radar returns and backscatter patterns
- thermal signatures and cold-trap persistence
- imagery, topography, slope, and roughness maps
- illumination patterns and shadow dynamics
- spectral indicators of composition
- surface morphology suggestive of impact, layering, or block fields
- rover or lander surface measurements where available

2.1.5 Sensing / evidence modalities

- orbital neutron spectroscopy
- radar sounding and radar backscatter
- optical and multispectral imaging
- thermal mapping
- laser altimetry / terrain analysis
- local in situ sensing from landed assets or rovers
- integrated inference across surface, orbital, and analog data

2.1.6 Resolution limits

- hydrogen proxy does not uniquely determine extractable ice state or geometry
- thermal suitability does not uniquely determine volatile accessibility
- radar and imagery may constrain morphology without resolving shallow mechanical behavior at construction scale
- orbital coverage and resolution can remain too coarse for local infrastructure decisions
- subsurface heterogeneity may remain unresolved at excavation or drilling-relevant scale

2.1.7 Coverage gaps

- local bearing strength and compaction behavior
- exact volatile form, continuity, and depth distribution
- excavation response of target materials
- trafficability under repeated use

- blast and ejecta response during repeated landings
- subsurface layering and void risk at site-specific construction scale
- long-duration operational response to disturbance

2.1.8 Evidence adequacy limits

Current evidence may support:

- elimination of clearly poor zones
- prospect ranking across broad regions
- first-pass identification of attractive volatile or access classes
- preliminary hazard screening
- bounded decisions about where additional prospecting should occur

Current evidence does not by itself support:

- definitive construction-grade site admissibility
- definitive volatile extraction viability
- certainty that a candidate site can absorb repeated traffic or landings
- certainty that early surface disturbance will not create path dependence around a mistaken site concept
- certainty that infrastructure should harden at the candidate location

2.1.9 False-confidence traps within Section 1

- mistaking volatile proxy strength for usable resource adequacy
- treating attractive illumination or ridge access as proof of infrastructure admissibility
- assuming terrain maps resolve construction-grade surface conditions
- over-reading orbital data as sufficient for excavation commitment
- confusing prospectivity with site readiness

2.1.10 Admissible vs inadmissible claims

Admissible:

- this region appears more promising than another for bounded follow-on prospecting
- this site likely warrants closer assessment under a controlled exploration logic
- this terrain class is less hazardous or more operationally favorable than another
- disturbance may be justified as a learning act under preserved optionality

Inadmissible:

- the site is ready for fixed infrastructure
- the volatile deposit is decision-adequate for ISRU dependence
- repeated traffic and landing are safe to assume
- surface hardening should proceed now

2.2. Ambiguity Persistence

2.2.1 Section purpose

This section identifies where the same lunar evidence still supports multiple materially different surface or subsurface realities.

2.2.2 Core question

What materially different lunar futures remain compatible with the current evidence?

2.2.3 Competing interpretations

The same observed conditions can imply:

- concentrated shallow ice vs distributed hydrogen-bearing regolith
- mechanically competent site vs deceptively fragile layered or blocky surface
- promising local resource signal vs low-access or non-scalable operating reality
- traversable corridor vs route that degrades under repeated use
- locally successful prospecting zone vs poor basis for long-horizon infrastructure concentration

2.2.4 Reducible ambiguities

These may narrow with added sensing or bounded prospecting:

- broad terrain suitability classes
- relative attractiveness among candidate prospecting zones
- major hazard clusters
- coarse volatile prospect ranking
- likely communication or illumination advantages among sites

2.2.5 Persistent ambiguities

These often remain structurally unresolved until disturbance:

- volatile geometry, form, and accessibility at working scale
- excavation response of regolith and target material
- repeated-traffic degradation
- shallow subsurface structural weakness or voids
- whether a local prospect scales into an infrastructure-supporting zone
- whether early site success generalizes into a durable surface architecture

2.2.6 Hidden assumptions

- strongest resource proxy equals best infrastructure site
- a locally attractive patch should anchor broader corridor or logistics design
- surface stability can be inferred from morphology alone
- repeated operations will behave like first operations
- power access or illumination advantage can compensate for unresolved subsurface risk

2.2.7 Sensitivity drivers

- volatile depth and form
- regolith mechanical heterogeneity
- trafficability degradation under repeated traverses
- illumination persistence and power continuity
- communication geometry and navigation dependence
- landing plume and blast effects
- excavation-induced changes to local terrain and observability

2.2.8 Operationally material ambiguity

- whether a candidate site is merely interesting or truly buildable
- whether a prospect supports only a localized sampling act or the beginning of corridor and logistics commitment
- whether repeated operations amplify risk faster than evidence improves
- whether the first surface architecture is resilient or fragile under growth

2.2.9 Capital- and mission-relevant ambiguity

- locking mission sequencing around an unresolved site
- hardening mobility plans before route behavior is known
- tying power or logistics design to a misleading local prospect
- building ISRU assumptions on evidence that remains non-unique

2.2.10 Canonical ambiguity formulation for lunar

This domain is dominated by hidden structure ambiguity with strong architectural consequences: the same orbital and local evidence can support materially different realities about resource accessibility, surface competence, corridor durability, and long-horizon site viability.

2.3. System / Environmental / Surface Response

2.3.1 Section purpose

This section defines how the lunar surface and near-subsurface change once disturbance, access, or infrastructure begin.

2.3.2 Core question

How does intervention change the site being evaluated, the evidence it produces, and the future viability of the local exploration architecture?

2.3.3 Immediate effects

- excavation and drilling directly disturb surface and shallow subsurface structure
- traffic compacts or loosens regolith depending on local conditions
- landing plumes redistribute fines and alter surface state
- local thermal regime may change with equipment, shadowing, or disturbed material
- volatile-bearing material may be mobilized or altered by exposure

2.3.4 Delayed effects

- repeated traverses harden corridors or degrade them
- local surface changes alter later measurements and interpretations
- blast protection, berms, or pad preparation reshape future operational geometry
- early infrastructure concentration changes what later siting choices remain practical
- surface modification creates latent governance and precedent effects

2.3.5 Coupled effects

- power placement shapes mobility range and future site dependence
- one corridor changes what other resource or science zones remain effectively reachable
- local excavation changes both physical conditions and the narrative of site adequacy
- repeated use converts reconnaissance into logistics structure
- communication and navigation architecture influence where disturbance is tolerated or encouraged

2.3.6 Measurement contamination / interpretive distortion

- post-disturbance evidence is no longer cleanly pre-commitment evidence
- excavated or trafficked sites may appear more legible while becoming less representative
- local operational success may be misread as broader site admissibility
- modified terrain can bias future planning toward the already-disturbed site

2.3.7 Externalities

- plume redistribution beyond the immediate site
- corridor hardening that constrains later alternatives
- local environmental alteration in permanently shadowed or thermally sensitive zones
- governance and coordination burden once one actor's infrastructure shapes shared access patterns

2.3.8 Path-dependent effects

- first landing site influences future landing logic
- first power node influences surface architecture
- first corridor influences where operations concentrate
- first excavation shapes later resource interpretation and system expansion
- first logistics concentration becomes difficult to undo

2.3.9 Irreversibility introduced by action

- site hardening changes the future baseline
- repeated traffic creates functional corridors
- pad preparation and berm emplacement define operational zones
- local infrastructure converts a prospect into a commitment anchor
- early physical success generates pressure to scale around the same site

2.3.10 Disturbance-trigger rule

Disturbance should be treated as a potential commitment trigger when it changes the evidentiary baseline, narrows future access geometry, or increases pressure to continue at the same location.

This applies even when the action is framed as exploration.

A trench, drill hole, landing disturbance, repeated traverse, emplacement, or localized excavation may produce useful evidence. It may also make later refusal harder by turning the affected site into the practical reference point for future work.

The governing question is therefore not only what the disturbance reveals.

It is what the disturbance makes harder to undo.

2.3.11 Canonical response formulation for lunar

This is a surface-response domain in which exploration is not neutral: the first disturbances and access decisions change terrain, observability, sequencing, and future admissibility.

2.4. Architecture Under Constraint

2.4.1 Section purpose

This section maps the enabling architecture that carries lunar work from signal to durable surface commitment.

2.4.2 Canonical progression

Sensing & Prospecting → Access & Mobility → Communications, Navigation & Data → Power & Resource Support → Surface Infrastructure & Logistics

2.4.2.1 Stage 1 — Sensing & Prospecting

This stage establishes the earliest evidence surface:

- orbital prospecting
- local terrain and hazard characterization
- volatile and compositional inference
- first-pass site and corridor ranking
- bounded prospect generation

What it unlocks:

- comparative region ranking
- elimination of clearly poor areas
- controlled advancement toward access logic

What it does not unlock:

- construction-grade site admissibility
- infrastructure commitment
- durable resource dependence

2.4.2.2 Stage 2 — Access & Mobility

This stage turns prospectivity into reachable operating geometry:

- rover path concepts
- landing access framing

- traverse design
- excavation or drill reachability
- logistics movement assumptions

What it unlocks:

- a coherent prospecting or site-test concept
- comparison among sites based on actual reach and use, not only signal quality
- better view of whether a site can be explored without prematurely hardening around it

What it creates:

- path bias toward reachable zones
- temptation to privilege access-favorable sites over evidence-adequate ones

2.4.2.3 Stage 3 — Communications, Navigation & Data

This stage activates the coordination layer:

- relay and line-of-sight logic
- navigation and localization support
- data-return architecture
- multi-asset coordination
- operational awareness for decision-making

What it unlocks:

- sustained operations beyond one-off prospecting
- better interpretation of where bounded exploration can continue safely
- more grounded refusal / defer / proceed basis

What it creates:

- infrastructure pressure to keep operating from the same local architecture
- narrative of persistence that may outrun site adequacy

2.4.2.4 Stage 4 — Power & Resource Support

This stage assembles the operational support chain:

- energy continuity
- thermal survival support
- resource handling support where relevant
- local system survivability
- enabling conditions for sustained work

What it unlocks:

- repeated operations if the site remains admissible
- longer mission windows and more ambitious surface acts

What it creates:

- dependence on one power geometry or local support architecture
- narrowing of reversible alternatives
- temptation to treat support infrastructure as proof of site adequacy

2.4.2.5 Stage 5 — Surface Infrastructure & Logistics

This is the stage where lunar work ceases to be exploratory and becomes structural:

- site hardening
- landing pads or prepared zones
- berms and blast protection
- fixed logistics nodes
- recurring corridors
- excavation-linked infrastructure
- concentrated surface system identity

2.4.3 Enabling assets

- prospecting sensors and analysis stack
- rovers and local mobility systems
- communications and navigation support
- power generation and survival systems
- excavation or drilling systems where relevant
- logistics handling and emplacement capability

2.4.4 Dependencies

- terrain and access geometry
- illumination and power continuity
- communications coverage and navigation reliability
- landing access and revisit profile
- local regolith response to traffic and modification
- sequencing of prospecting versus buildout

2.4.5 Coordination requirements

- prospecting and operations alignment
- mobility and communications coordination
- power and logistics coordination
- mission-sequencing discipline
- governance discipline to preserve refusal before lock-in

2.4.6 Logistics burden

- surface transport and revisit burden
- mass delivery constraints

- site support staging
- local emplacement of support systems
- repeated operational dependence on one surface concept

2.4.7 Governance burden

- preserving refusal authority after first local success
- distinguishing bounded prospecting from implicit site selection
- refusing corridor or infrastructure hardening before evidence is adequate
- preventing local operational convenience from substituting for site admissibility

2.4.8 Hidden lock-in points

- choosing one access-favorable site too early
- letting first corridor become the default corridor
- anchoring future work to one power node before alternatives remain comparable
- converting volatile interest into infrastructure dependence before resource adequacy exists
- treating surface preparation as operational housekeeping rather than commitment

2.4.9 Sequencing traps

- hardening landing or traffic pathways before local ground adequacy is known
- scaling from one prospecting success to fixed infrastructure logic
- assuming resource promise justifies logistics concentration
- letting communications or power persistence force a single-site future

3. Commitment Thresholds

3.1. Section purpose

This section defines the actual boundary between reversible lunar exploration and durable surface commitment.

3.1.1 Core question

When is lunar advancement admissible, and when should the mission still defer or refuse hardening moves?

3.1.2 Reversible actions

- orbital prospect ranking
- bounded local sensing
- comparative site and corridor screening
- limited reconnaissance traverses
- conceptual architecture work that preserves alternatives
- strictly bounded sampling or test planning

3.1.3 Commitment actions

- site hardening
- pad preparation or berm emplacement

- corridor establishment through repeated use or design
- fixed power or logistics emplacement
- excavation or drilling tied to enduring infrastructure assumptions
- resource dependence that presumes local adequacy
- architecture choices that make alternative sites effectively non-viable

3.1.4 Commitment trigger register

The following triggers should be treated as commitment-proximate even before formal infrastructure exists.

T-LUN-1: Site fixation
A candidate site becomes the working reference location for planning, sequencing, or repeated operations.

T-LUN-2: Access repetition
A route is used or designed repeatedly enough that it begins to function as the default corridor.

T-LUN-3: Power-node anchoring
Power placement, illumination logic, or survival support begins to privilege one operating geometry.

T-LUN-4: Communications and navigation anchoring
Relay, localization, or data-return architecture makes one site or corridor easier to continue than alternatives.

T-LUN-5: Disturbance-based verification
Excavation, drilling, trenching, sampling, or landing effects alter the evidence base while also increasing local operational dependence.

T-LUN-6: ISRU dependency formation
A resource assumption begins to shape power, logistics, excavation, processing, or mission-sequencing decisions.

T-LUN-7: Surface hardening
Pad preparation, berms, blast protection, graded zones, or repeated traffic convert an exploratory site into an operational site.

T-LUN-8: Programmatic designation
A site, corridor, or resource zone becomes treated as primary in public, institutional, mission, or partner materials.

A trigger does not need to be permanent to matter.

It matters when it reduces the practical ability to refuse, defer, re-site, or preserve alternatives.

3.1.5 Evidence required before crossing

At minimum:

- a candidate site that remains plausible after integrated terrain, hazard, and resource assessment
- evidence that access and mobility do not silently defeat the site concept
- evidence that repeated operations are not likely to create unacceptable degradation or lock-in before learning value is realized
- evidence that the local architecture can remain bounded if the site proves less adequate than hoped
- evidence that remaining ambiguity is tolerable relative to the scale of planned hardening

3.1.6 Remaining tolerable uncertainty

Tolerable:

- bounded uncertainty in exact volatile geometry or site optimization if downside remains survivable and alternatives remain open
- uncertainty that does not plausibly flip the site from workable to structurally compromised once repeated operations begin

Not tolerable:

- uncertainty that could make excavation, repeated traffic, or fixed support fundamentally mis-sited
- dependence on optimistic resource accessibility assumptions
- surface hardening before ground behavior or local architecture survivability is legible
- ambiguity that could convert first-access into irreversible error

3.1.7 Lock-in map

What becomes harder to reverse after crossing:

- site identity
- access and corridor logic
- power geometry
- logistics concentration
- resource-dependence narrative
- willingness to re-site after local infrastructure appears
- governance flexibility around shared or repeated use

3.1.8 Optionality half-life

Optionality decays as soon as continued use becomes easier than reconsideration.

In lunar systems, optionality does not disappear at one dramatic moment. It decays through repeated use, support placement, operational convenience, and institutional expectation.

The half-life is shortest when several forms of dependence accumulate together:

- a site becomes the working reference location
- a route becomes the default access path
- power support is placed around one operating geometry
- communications and navigation support privilege one zone
- excavation or sampling changes the local evidence baseline
- ISRU assumptions enter future mission design
- public or partner materials normalize the selected site

At that point, refusal may remain theoretically possible while becoming operationally or institutionally non-credible.

That is the point at which commitment has begun.

3.1.9 Reversibility cost

Costs of delaying crossing are often modest compared with:

- hardening the wrong site

- concentrating logistics around a misleading prospect
- building corridors that later constrain better options
- scaling ISRU or infrastructure on non-decision-adequate evidence

3.1.10 Governance burden

Before crossing, the mission must preserve:

- refusal authority after local success or early emplacement
- ability to re-rank sites, corridors, and sequence
- willingness to stop after bounded learning
- discipline against convenience-led hardening

3.1.11 Reversibility ladder

Lunar actions should be classified by reversibility class, not only by mission phase.

1. **Reversible**: Orbital prospect ranking, broad site comparison, non-hardening analysis, and conceptual architecture work that preserves alternatives.
2. **Partially reversible:** Bounded local sensing, limited rover traverses, local measurements, preliminary access concepts, and strictly bounded sampling plans.
3. **One-way door:** Landing zone preparation, repeated corridor use, fixed power placement, excavation tied to future use, or subsurface access that begins to anchor architecture.
4. **Precedent-setting:** Programmatic designation of a primary site, shared infrastructure dependence, ISRU architecture dependence, or repeated surface use that becomes the assumed development pathway.

The classification is governed by refusal credibility.

An action is not reversible simply because hardware can be removed. It is reversible only if the mission can still refuse, re-site, or re-sequence without inheriting the action as a constraint.

3.1.12 Proceed conditions

Proceed when:

- the site hypothesis is not merely promising but bounded enough to support staged commitment
- access, mobility, and support architecture do not silently dominate the decision
- remaining ambiguity is bounded and survivable
- the local system can absorb likely downside without hidden ruin dynamics
- hardening acts are sequenced after evidence rather than before it

3.1.13 Defer conditions

Defer when promising evidence exists but local ground behavior, volatile accessibility, access geometry, or support architecture remains too unresolved to justify hardening.

Defer is a non-commitment state.

It does not authorize quiet preparation for site hardening. It does not authorize corridor normalization. It does not authorize power, communications, or logistics placement that makes one site the assumed future.

During Defer, admissible actions are limited to bounded evidence acquisition that preserves refusal, re-siting, and site comparison.

Defer applies when:

- promising evidence exists but local ground behavior or access geometry remains too unresolved
- additional bounded prospecting can materially improve admissibility judgment
- power, logistics, or corridor logic is pushing ahead of site adequacy
- disturbance may reduce uncertainty but would also create commitment pressure
- a site remains attractive but not yet decision-adequate
- support architecture is beginning to make continuation easier than refusal

A Defer determination should identify the specific evidence update that could change admissibility and the condition under which continued study must stop.

3.2. Refuse conditions

Refuse when the proposed action would create irreversible or hard-to-reverse exposure that current evidence cannot justify, and when the dominant uncertainty cannot be reduced without crossing the same commitment threshold.

Refuse applies when:

- the action depends on an optimistic resource interpretation that remains unresolved
- site, corridor, power, or support architecture would become difficult to abandon
- disturbance would alter the evidence baseline without sufficient decision-relevant gain
- ISRU dependency would enter the architecture before volatile form, accessibility, continuity, or concentration is decision-adequate
- future refusal, re-siting, or re-sequencing would become non-credible after the action proceeds
- Defer would function as quiet preparation for commitment rather than preserved optionality

A Refuse determination does not invalidate lunar exploration. It invalidates the proposed commitment under current evidence and authority conditions.

3.3. Factor interdependencies

3.3.1 How factors propagate across sections

Lunar is tightly cross-coupled. Resource interpretation, access, power, and logistics all shape one another, and early operations recursively change future admissibility.

1. **Dominant coupling**

The dominant lunar coupling is:

volatile interpretation × access geometry × power support × surface disturbance

A volatile signal may identify an attractive target. Access and illumination may make one site operationally convenient. Power and communications may then reinforce that site. Disturbance may produce knowledge while altering the evidence base. Together, these factors can convert a prospect into an infrastructure anchor before the subsurface state has been resolved.

This is the core pathway from signal to commitment.

2. **Volatile interpretation**

Influences:

- **Detectability Limits** through what orbital evidence can actually resolve
- **Ambiguity Persistence** because one proxy can fit multiple resource realities
- **Power & Resource Support** inside Section 4
- **Commitment Thresholds** because optimistic resource reading drives premature ISRU or site hardening

3. **Surface competence and trafficability**

Influences:

- **Detectability Limits** because terrain imagery does not fully resolve operational ground behavior
- **Ambiguity Persistence** through competing interpretations of seemingly favorable sites
- **Surface Response** because repeated use changes the site
- **Access & Mobility** inside Section 4
- **Threshold criteria** because repeated operations are often the actual beginning of commitment

4. **Illumination and power continuity**

Influences:

- **Detectability Limits** by shaping what is operationally visible as attractive
- **Architecture Under Constraint** through power geometry and support survivability
- **Commitment Thresholds** because power convenience can bias site choice ahead of evidence adequacy

5. **First-access site choice**

Influences:

- **Ambiguity Persistence** by privileging one local interpretation over comparable alternatives
- **Surface Response** because first acts reshape future conditions
- **Architecture Under Constraint** by anchoring mobility, communications, and logistics
- **Irreversibility map** because first site choice is one of the strongest lock-in points

6. **Corridor formation**

Influences:

- **Surface Response** through repeated traverses and compaction
- **Architecture Under Constraint** by defining future reachable zones
- **Commitment Thresholds** because a corridor can become durable before it is formally recognized as commitment

3.3.2 7. Power and logistics emplacement

Influences:

- **Architecture Under Constraint** by turning exploration into a supported operating system
- **Irreversibility map** through infrastructure concentration
- **Threshold criteria** because once support nodes exist, refusal becomes institutionally harder

3.3.3 Canonical interdependency rule for lunar

In lunar systems, prospecting, access, power, and logistics do not simply support exploration. They co-produce the surface commitment surface.

3.4. Critical uncertainties

The most decision-dominant uncertainties in this vertical are:

- volatile form, accessibility, and local continuity
- actual surface competence under repeated use
- excavation and drilling response at working scale
- whether access-favorable sites are also infrastructure-admissible sites
- whether early support architecture creates lock-in faster than evidence improves

3.5. False-confidence traps

- treating the strongest resource proxy as the best infrastructure site
- confusing attractive illumination with admissibility
- mistaking a successful first traverse for corridor adequacy
- assuming local surface success generalizes into long-horizon viability
- treating early power or comms support as evidence of site adequacy
- allowing convenience and persistence to substitute for threshold judgment

3.6. Irreversibility map

The major hardening moves in lunar are:

- first site fixation
- repeated route use becoming corridor establishment
- power-node emplacement
- communications or navigation anchoring
- landing pad or blast-protection preparation
- excavation tied to enduring local architecture
- subsurface access that becomes the reference point for later work
- logistics concentration around one site concept
- resource dependence built on unresolved evidence
- public or institutional treatment of one site as primary

These moves matter because they can make reversal non-credible before full construction occurs.

3.6.1 Lunar irreversibility classes

1. **Physical disturbance irreversibility**: Surface or subsurface alteration changes the baseline for later evidence, operations, and governance.
2. **Access and corridor irreversibility:** Repeated movement or route improvement turns exploration geometry into future logistics geometry.

3. **Power and support irreversibility:** Energy, communications, navigation, or survival support begins to privilege one local architecture.
4. **Resource-dependency irreversibility:** ISRU assumptions enter mission design before volatile form, accessibility, or continuity is decision-adequate.
5. **Precedent irreversibility:** A site, corridor, or resource zone becomes treated as primary before the evidence has earned that role.
6. **Coupled irreversibility:** Individually manageable actions combine into lock-in: site preference, access, power, disturbance, and resource narrative reinforce one another.

3.6.2 Irreversibility statement

A lunar pathway becomes structurally irreversible when early actions make one site, corridor, or resource interpretation harder to abandon than to continue.

3.7. Threshold criteria

3.7.1 Minimum threshold tests before commitment becomes admissible

A lunar project or mission path should not harden into durable surface commitment unless all of the following are true:

1. **Site plausibility is bounded, not merely attractive**

- the candidate site remains credible after integrated terrain, hazard, and resource assessment
- the case is not based only on one favorable proxy such as illumination or hydrogen signal
- the key unknowns are explicit rather than hidden beneath a promising local picture

2. **Prospecting and access preserve optionality**

- mobility and approach logic do not silently force a single-site future
- bounded prospecting can still stop cleanly
- first-access success does not automatically dictate architecture commitment

3. **Remaining ambiguity is survivable**

- unresolved uncertainty does not plausibly flip the site from workable to structurally compromised
- the downside case does not create hidden ruin dynamics for the mission architecture
- the project is not dependent on one optimistic resource or ground interpretation

4. **Repeated operations will not create premature lock-in**

- traffic, excavation, or repeated landing logic does not harden the site faster than evidence improves
- corridor formation and site preparation remain bounded and intentional
- the system can still re-site or down-scope if new evidence worsens the case

5. **Support architecture has not outrun evidence**

- power, communications, and logistics systems remain provisional until site adequacy improves
- the mission has not capitalized one local future before it is decision-adequate
- infrastructure is not being used to justify itself

6. **Governance and refusal authority remain intact**

- the team can still re-rank sites and sequence
- stopping after learning remains a live option
- no political, institutional, or mission-design structure has made continuation compulsory before evidence is adequate

7. Commitment triggers remain controlled

- no site, corridor, resource assumption, or support architecture has become the default pathway without admissibility review
- trigger-proximate actions are treated as commitment-bearing, not preparatory
- third-party or partner actions do not create irreversible exposure on behalf of the mission
- Defer has not been used as a ramp toward commitment
- any allowed disturbance remains bounded by a decision-relevant evidence question

3.7.2 Threshold failure indicators

The threshold has not been met when one or more of the following are true:

- site choice depends on optimistic resource accessibility assumptions
- access or mobility convenience is carrying the site case
- corridor logic is hardening before local ground behavior is legible
- power and logistics support are being placed ahead of site admissibility
- disturbance would create commitment pressure without sufficient learning value

3.7.3 Canonical threshold statement

Lunar commitment becomes admissible only when site plausibility, access survivability, repeated-operation effects, and support-architecture dependence are all legible enough that the mission can absorb remaining uncertainty without hidden structural compromise.

3.7.4 Canonical signal-to-decision statement

The lunar decision problem is not whether a signal is promising.

It is whether the signal has earned the authority to shape commitment.

A signal becomes decision-grade only when the remaining ambiguity no longer controls site selection, access geometry, support architecture, disturbance planning, or resource dependency.

Until then, the admissible path is bounded learning under preserved refusal authority.