Earth: Day Zero — Paper III

The Lunar Consequence

A Minimal Exit-to-Moon Continuity Test

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Frozen Canonical Version v1.0

Frozen canonical version.

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Abstract

Frozen Paper I established the Day Zero geometric sequence proposed for testing: Antarctic Entrance → Hawai'i/Mauna Kea Middle Mountain → Arctic Exit. Frozen Paper II then asked whether one planetary event could generate those Earth-side responses while leaving a recognizable, gravitationally coherent Earth. [1,2]

Paper III asks the next question in its simplest form: **if the Arctic exit-domain response from that same event ejects material, could enough of that material remain with Earth and later become the Moon?** Paper II explicitly separated a far-side response from a literal through-Earth material path; Paper III preserves that distinction and does not require an intact projectile to traverse the planet. [2]

The Arctic exit is not treated as the finished Moon. It identifies a proposed source domain, not a required launch direction. Material generated by a giant planetary event may reaccrete with the post-event Earth, escape the Earth system, or remain in a circumterrestrial branch that later collides, accretes, melts, cools, differentiates, and undergoes orbital evolution. The relevant gravity is the evolving post-event Earth–material system, not present-day Earth imposed retroactively. Established lunar-origin studies already show that post-impact material can occupy Earth-bound lunar-forming states through more than one subsequent history. [3,5,12,13]

Paper III therefore imposes only four burdens: enough candidate material must enter the lunar branch; enough must remain gravitationally associated with Earth; the surviving reservoir must be broadly compatible with the Moon's silicate-rich, low-metal geochemical character; and the post-event mass and angular momentum must permit later lunar evolution. Predominantly terrestrial provenance is a specific Day Zero prediction to be tested, not a fact assumed from isotopic resemblance alone. [3,15,16,18,19]

This is not a complete Moon-formation simulation. It is a minimal continuity test: **did enough Earth come out, stay with Earth, and remain physically capable of becoming the Moon over time?**

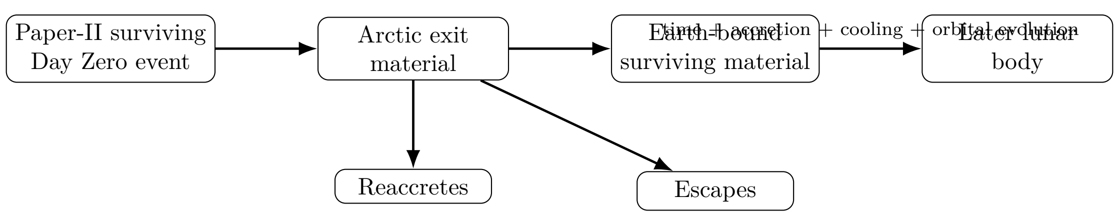

Figure 1: Minimal Paper-III logic. The proposed Arctic exit is the source domain for the lunar branch, not the finished Moon. Only material that remains in the circumterrestrial branch can contribute to the later Moon; material that reaccretes with Earth or escapes cannot be counted toward the lunar outcome.

1. Research Status and Scope

Paper I asked where. Paper II asked whether one event could physically do it. Paper III asks whether enough material from that same event could later become the Moon.

Paper III inherits Papers I and II without reopening their geometry or Earth-side mechanics. [1,2] The Day Zero branch tested here is straightforward:

$$\text{Antarctic Entrance} \rightarrow \text{global planetary response} \rightarrow \text{Arctic Exit}$$
$$\rightarrow \text{Earth-bound ejecta} \rightarrow \text{Moon over time.}$$

The phrase "Moon over time" is important. Paper III does not require material emerging from the Arctic exit to possess the Moon's present shape, orbit, internal differentiation, or tidal state at the instant of the event. The modern Moon is the endpoint of later evolution, not the exit feature itself.

The canonical distinction is therefore simple: **the Arctic/North-polar exit is a source domain, not a lunar mold**. Later evolution may reshape and assemble material produced by the same event; it may not replace that material with an unrelated source.

The selected question is therefore:

> **Can the same event that survives Paper II produce enough lunar-candidate material from the proposed Arctic exit-domain response, keep enough of that material associated with Earth, and leave a physically admissible starting state for the later Moon?**

Paper III is therefore a *conditional consequence test*. It does not promote literal trans-Earth material transfer to an established Paper-II result. If the lunar branch fails, that failure rejects the Day Zero lunar consequence without automatically erasing the weaker Paper-II possibility of a non-material far-side response.

No second impact may be introduced to make the Moon after the Earth-side event has already been selected.

1.1 The Four Core Burdens

The lunar branch only needs to clear four basic hurdles before we worry about the details of four billion years of later evolution.

Burden	Minimum requirement
Enough material	The same Day Zero event must displace a lunar-relevant amount of material into the Arctic-exit branch.
Enough stays with Earth	A substantial fraction must remain gravitationally associated with the post-event Earth system rather than all reaccreting or escaping.
Right broad material	The surviving reservoir must be silicate-rich and low in metal, and its measured provenance must be compared with Earth–Moon geochemical constraints rather than assumed from them.
No system contradiction	The mass and angular momentum of the surviving Earth–material system must permit later evolution toward a lunar-scale satellite.

Table 1: The deliberately minimal Paper-III burden. Detailed accretion, thermal, volatile, and tidal histories are not promoted to independent mechanisms in this paper.

2. The Arctic Exit Is Not the Finished Moon

The exit is where the material leaves the Earth-side event. The Moon is what some of that material may become later.

Paper III separates *source event* from *finished satellite*. If the Arctic exit-domain response ejects material, that material can have only a few broad long-term fates: it can reaccrete with the evolving post-event Earth, escape the Earth system, or remain gravitationally associated long enough to participate in later lunar assembly.

The last branch does not need to begin as the modern Moon. Giant-impact studies demonstrate that Earth-bound lunar material can evolve through different post-impact histories before a stable satellite is established. [7, 10, 11, 13] Paper III therefore does not choose a detailed accretion pathway in advance.

The continuity rule is stricter and simpler: material credited to the Moon must originate in the *same Day Zero event*. Time after the event is allowed. A second unrelated source event is not.

2.1 Exit Domain Does Not Fix the Exit Trajectory

Saying the material came out through the Arctic tells us where the lunar branch begins. It does not require every piece of material to travel straight outward from the pole.

The Arctic exit is a geographic source domain in the Day Zero reconstruction, not a prescribed velocity vector. Material emerging from that domain may carry radial and tangential motion inherited from the collision, the deforming Earth, and the global response. Paper III therefore does not assume that all lunar-candidate material leaves exactly along the local surface normal.

This distinction matters because an exactly radial parcel has little or no specific orbital angular momentum about Earth. In the idealized limit, $\mathbf{r}$ and $\mathbf{v}$ are parallel and

$$\mathbf{h} = \mathbf{r} \times \mathbf{v} \approx 0.$$

Such material is more naturally placed on a reaccretion or escape trajectory than on a long-lived lunar-forming one. A viable Day Zero lunar branch must therefore produce a nontrivial subset of Arctic-exit material with sufficient non-radial motion to remain dynamically useful. This is an output requirement, not a new mechanism imposed in advance. [3, 4]

3. Minimal Mass Accounting

A lot of material can leave the surface without becoming the Moon. We only count what survives in the Earth system.

For final-fate bookkeeping after the immediate hydrodynamic phase, let the candidate mass associated with the Arctic-exit branch be written

$$M_{\text{exit}} = M_{\text{reacc}} + M_{\text{bound}} + M_{\text{esc}},$$

where M_{reacc} ultimately returns to Earth, M_{esc} ultimately leaves the Earth system, and M_{bound} remains gravitationally associated with Earth over the selected post-event accounting interval. These are fate categories, not claims that each parcel enters its final category instantaneously.

The first lunar requirement is therefore not

$$M_{\mathrm{exit}} \approx M_{\mathrm{L}},$$

but rather that the surviving bound component be large enough that later accretion and loss can still produce a Moon of approximately the observed mass. Classical and later lunar-accretion calculations explicitly show that not all initially orbiting material becomes the final Moon. [7, 10, 11]

This is intentionally coarse. Paper III does not yet need to know whether the bound reservoir initially looks like discrete ejecta, a disk, a hot extended structure, or a rapidly assembled satellite seed. It only needs enough viable Earth-bound mass.

4. Staying With Earth Without Immediate Reaccretion

The useful material has to do two things at once: remain gravitationally associated with Earth and avoid immediate reaccretion.

For a parcel of candidate material at distance r from the surviving post-event Earth with speed v, the simplest first-order specific orbital-energy check is

$$\varepsilon = \frac{v^2}{2} - \frac{GM_{\mathrm{post}}}{r},$$

where M_{post} is the mass of the surviving post-event Earth. Material with $\varepsilon < 0$ is gravitationally bound in this deliberately simplified two-body check. A full calculation must use the evolving post-impact potential rather than assume the present Earth mass, shape, rotation, or field state. Binding alone is not sufficient, because bound material with too little angular momentum may promptly reaccrete. The corresponding specific angular momentum is

$$\mathbf{h} = \mathbf{r} \times \mathbf{v}.$$

These two quantities provide all the orbital bookkeeping Paper III needs at this stage. The paper does not require the material to begin at the Moon's modern orbital distance, inclination, or eccentricity. It requires a nontrivial population that is both Earth-bound and dynamically capable of surviving long enough to participate in later lunar assembly.

5. Why an Earth-Derived Branch Is Worth Testing

Moon rocks look strikingly Earth-like. That does not prove Day Zero, but it makes the source of the lunar material an obvious test.

The Earth and Moon show unusually close silicate-isotope relationships across several systems, although precision measurements also resolve small differences and later processing matters. [14–18] The Moon also contains only a small metallic core compared with Earth. [3, 19]

Those observations do not prove that the Moon was expelled from Earth. They do make material provenance a direct consistency check for any Moon-forming branch. The resemblance is not uniquely diagnostic of a terrestrial source: post-impact equilibration and formation from compositionally similar source reservoirs have also been proposed, and vanadium-isotope results have been interpreted as compatible with a substantially impactor-derived canonical Moon. [8, 18]

Paper III therefore asks only two broad compositional questions:

1. Is the surviving lunar-forming reservoir substantially derived from terrestrial silicate rather than being overwhelmingly unrelated impactor material?
2. Is it sufficiently metal-poor that a Moon with a small metallic core can emerge without an arbitrary late iron-removal step?

The exact proto-Earth fraction is not frozen in advance. Nor does Paper III use the word "identical" as a blanket description of Earth and Moon composition. The event output must be compared with the actual geochemical record rather than with a slogan. [15, 16]

The Moon's hot differentiated history and depletion in many moderately volatile elements are retained only as downstream consistency checks. [3, 20, 21] A hot or partially vapor-bearing post-event reservoir is not intrinsically problematic for a giant-impact branch. [3, 12] Paper III does not require a detailed volatile-loss or magma-ocean chronology.

6. Angular Momentum: A Sanity Check, Not a New Story

The event cannot merely throw out enough rock. The surviving Earth and that rock must also carry a physically workable amount of spin and orbital motion.

Giant-impact lunar-origin models are strongly constrained by Earth–Moon angular momentum. [3, 4, 9] Paper III therefore retains one system-level check. Schematically, the post-event angular momentum is partitioned among the surviving Earth, retained circumterrestrial material, and escaping material:

$$\mathbf{L}_{\text{tot,after}} = \mathbf{L}_{\text{Earth}} + \mathbf{L}_{\text{bound}} + \mathbf{L}_{\text{esc}}.$$

A full calculation must conserve the total angular-momentum vector and include spin and orbital contributions of all relevant remnants; the expression above is only the Paper-III bookkeeping partition.

The immediate post-event value does not have to equal the modern Earth–Moon state. Later tidal and orbital evolution is expected, and high-angular-momentum lunar-origin scenarios explicitly explore subsequent angular-momentum evolution. [9] Paper III merely rejects an exit branch that can produce lunar mass only by placing the surviving system in an obviously impossible angular-momentum state.

Detailed resonance, tidal, and despinning histories are intentionally deferred.

7. One Event, One Continuity Rule

We do not get one collision to make the Earth features and another one to make the Moon.

Paper III inherits the same event state that survived Paper II. The Earth-side result may not be retuned after the fact merely to improve the lunar outcome.

The continuity rule is therefore simple:

$$\Pi_{\text{Paper II}} = \Pi_{\text{Paper III}}.$$

The Moon-forming branch may involve later evolution of material generated by that event, but it may not require a new unrelated source event.

This distinction is central. *Time* after the event is allowed. A second ad hoc cause is not.

8. Minimum Calculation Needed

We do not need a four-billion-year supercomputer movie. We need four outputs from the event that survives Paper II.

For each Paper-II-surviving event state, the minimum useful Paper-III calculation should report:

1. **Mass fate:** how much material enters the Arctic-exit branch, and how much reaccretes, escapes, or remains circumterrestrial;
2. **Dynamical retention:** whether a nontrivial bound population avoids prompt total reaccretion;
3. **Material character:** the broad terrestrial-silicate provenance and metal fraction of the surviving reservoir; and
4. **System angular momentum:** whether the surviving Earth plus bound material occupies a physically workable post-event state.

If those four outputs are compatible with later formation of a lunar-scale satellite, Paper III has done its job. Detailed accretion, cooling, and differentiation remain downstream; coupled tidal and electromagnetic consequences are reserved for Paper IV.

9. Falsification Architecture

The simple version is also easy to kill. If enough Earth cannot leave, stay, and become a Moon, the lunar branch fails.

The Day Zero lunar branch is materially weakened or rejected if any of the following holds:

1. **Mass failure:** the Paper-II event cannot produce enough candidate material in the Arctic-exit branch.
2. **Retention failure:** nearly all useful material either reaccretes or escapes, leaving no plausible circumterrestrial lunar reservoir.
3. **Dynamical failure:** the bound material cannot avoid prompt reaccretion or leads to an obviously impossible Earth–Moon angular-momentum state.
4. **Composition failure:** the surviving reservoir is fundamentally incompatible with the Moon's silicate-rich, Earth-like, low-metal character.

5. **Continuity failure:** a Moon can be made only by changing the event that survived Paper II or by introducing a second unrelated formation event.

These are intentionally broad. Paper III should fail for a basic physical reason before the program spends effort on detailed downstream evolution.

10. Permitted Paper-III Verdicts

The result can be promising, unresolved, disfavored, or dead. We do not need to pretend one calculation proves the whole Moon story.

Paper III permits four verdicts:

1. **Lunar branch physically admissible:** at least one Paper-II-surviving event produces enough Earth-bound, broadly Moon-compatible material to support later lunar evolution.
2. **Partially admissible / unresolved:** the basic mass-transfer branch remains physically possible, but one or more core outputs have not yet been demonstrated under the same event state.
3. **Disfavored:** a lunar outcome appears possible only under strongly tuned or mutually inconsistent assumptions.
4. **Falsified at Paper III:** no Paper-II-surviving event can produce a viable Earth-bound lunar reservoir without breaking an upstream requirement.

The frozen v1.0 status is **UNRESOLVED**. Existing lunar-origin literature establishes that giant impacts can place substantial material into Earth-bound lunar-forming states and can produce Earth-rich lunar material in some regimes. [6, 9, 12, 13] No Day Zero-specific calculation has yet demonstrated that the same event satisfying Papers I and II also clears the minimal Arctic-exit mass-transfer test.

11. What Paper III Does Not Establish

A successful Paper III gives us a viable lunar starting reservoir, not the finished modern Earth–Moon system.

Paper III does not establish:

- a unique impactor identity, mass, speed, angle, or composition;
- a literal intact projectile traversing Earth; Paper III requires only that the Arctic exit-domain response eject a lunar-candidate material branch;
- a unique disk, vapor, or rapid-accretion pathway;
- the exact initial lunar orbit or complete tidal migration history;
- the detailed lunar thermal, volatile, or differentiation chronology;

- the origin, persistence, or function of a coupled Earth–Moon dynamical or electromagnetic system, which is reserved for Paper IV; or
- the truth of the complete replacement-level Earth: Day Zero framework.

A successful Paper III would establish only that the same surviving Day Zero event can plausibly generate an Earth-bound, predominantly terrestrial reservoir from which the Moon may subsequently evolve.

12. Advancement Condition

First show that enough Earth came out, stayed with Earth, and could become a Moon. Only then solve the long history afterward.

Earth: Day Zero advances beyond Paper III only if a nonempty subset of the frozen Paper-II event space produces a physically credible Earth-bound lunar reservoir without changing the upstream event.

Only then does Paper IV ask what persistent coupled Earth–Moon dynamical and electromagnetic system that formation may have created.

Did enough Earth come out, stay with Earth, and become the Moon?

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