# Earth: Day Zero — Paper II

## The Event Class

A First-Principles Physical Test of the Entrance–Middle Mountain–Exit Sequence

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Frozen Canonical Version v1.0

Frozen canonical version v1.0 — Earth: Day Zero, Paper II.

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**Abstract**

Paper I of *Earth: Day Zero* isolated the geometry first: Antarctic Entrance → Hawai'i/Mauna Kea Middle Mountain → Arctic Exit, with the modern Middle Mountain expression permitted to have been modified by the later approximately 256 Ma Aegean–Everest–Mariana event. Paper II asks the next and narrower question: **what class of single physical event could generate all three response domains while leaving Earth gravitationally coherent?**

The words *entrance* and *exit* remain reconstruction labels rather than pre-proven mechanical descriptions. An Arctic "exit" does not initially require an intact body to traverse Earth. Large impacts can transmit stress and seismic energy through and around a spherical planet and can enhance antipodal response without material transit. [3–6]

Paper II therefore compares three progressively stronger event classes: (A) a primary giant impact with global-wave and antipodal response; (B) a deep-coupled giant impact producing larger-scale planetary redistribution without requiring through-transit; and (C) literal penetrating or trans-Earth material transfer. The paper imposes the same basic burden on every class: one physically transparent parameter set must account for the Antarctic primary response, a meaningful Middle Mountain response, the Arctic far-side response, and survival of a recognizable Earth. Conservation of mass, momentum, and energy; impact scaling; whole-Earth propagation; and gravity-regime disruption limits are the controlling filters.

Published idealized impact calculations establish that a planetary response need not be confined to the source and antipode; wave interference can also produce a physically distinct intermediate surface response. [18, 19] Paper II uses that result only for physical admissibility, not as a numerical Day Zero target. The developmental toroidal observation is retained only briefly as a survival possibility: if a strong circumferential redistribution mode appears naturally in a surviving solution, it may be recorded, but it is never imposed as a requirement or rescue mechanism.

The Moon-forming consequence, lunar capture, Earth–Moon angular momentum, the Earth–Moon alternator, and prescribed rotating-viscoelastic mechanics remain outside Paper II. The present event-class verdict remains **partially admissible / unresolved**: established physics permits the required categories of global response in principle, but no single constrained event model has yet demonstrated all three inherited domains and planetary survival simultaneously.

# 1. Research Status and Scope

*Paper I asked whether the three places form a meaningful geometry. Paper II asks what kind of single physical event could make that geometry without destroying the planet.*

Paper II begins only after the Paper-I geometry has been specified. It does not reopen the selection of Antarctica, Hawai'i/Mauna Kea, or the Arctic, and it does not use a mechanical model to improve the geometric fit after the fact.

The selected physical question is:

> **Does there exist a physically admissible, non-disruptive event class capable of producing a primary Antarctic disturbance, a physically meaningful Middle Mountain response compatible with the inherited domain, and an Arctic antipodal or exit-domain response under one common set of initial conditions?**

This is an event-class paper, not a full initial-value simulation. It is designed to identify the minimum physical constraints that any later numerical model must satisfy and to reject event descriptions that violate them before computational detail is added.

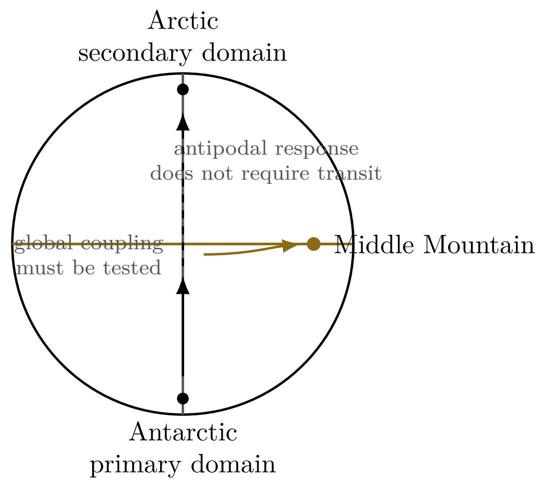


Figure 1: Paper-II physical burden, shown schematically and not to scale. The inherited Paper-I geometry is fixed. Paper II tests what type of single event can physically couple the three domains. The Arctic domain is initially treated as a secondary or antipodal response; literal material exit is a stronger hypothesis tested separately.

### 1.1 Paper-II Burden at a Glance

*There are only four required outcomes: the Antarctic side responds, the Middle Mountain responds, the Arctic side responds, and one recognizable Earth is left afterward.*

### 1.2 Inherited Canon from Paper I

Paper II inherits the following without alteration:

- the ordered geometry Antarctic Entrance → Hawai'i/Mauna Kea Middle Mountain → Arctic Exit;
- a broad formative interval of approximately 4.544 Ga to 4.096 Ga, with no exact Day Zero date asserted;
- the later approximately 256 Ma ABC event only as a pre-existing sequence correction relevant to the modern position of the Middle Mountain;
- no Wilkes Land target;
- no Mariana Day Zero exit;
- no exact pre-displacement Hawai'i coordinate;
- and no evidentiary use of the torus-like visual resemblance; a toroidal-like deformation mode may be examined only as a downstream survival hypothesis.

The 256 Ma correction is therefore *kinematic history*, not a free mechanical parameter in Paper II.

| Inherited element | Minimum physical burden | What Paper II does not assume |
|---|---|---|
| Antarctic Entrance | A primary coupled disturbance of planetary scale must be produced in the inherited Antarctic domain. | The mapped affected-domain width is not treated as the projectile diameter. |
| Middle Mountain | The same event must generate a physically meaningful intermediate response compatible with the inherited Hawai'i/Mauna Kea domain. | The model may not be aimed or retuned toward Hawai'i after the response field is calculated. |
| Arctic Exit | The same event must generate a compatible far-side or antipodal response. | Literal projectile or material transit through Earth is not required unless independently demonstrated. |
| Planetary survival | The event must leave a gravitationally coherent, recognizable Earth able to continue through later ABC history. | Merely leaving some large remnant is not sufficient. |

Table 1: The complete Paper-II burden in compact form. All four rows are required under the same event description.

### 1.3 Evidence-Use Rule

*The references establish pieces of impact physics; they do not prove that Day Zero happened.*

The external literature in Paper II is used for bounded purposes: collision-regime scaling, shock and seismic propagation, crater and ejecta physics, early-Earth thermal state, and post-impact relaxation. None of those sources is treated as independent evidence for the specific Antarctic–Middle Mountain–Arctic reconstruction. That reconstruction is inherited from frozen Paper I. [25] Paper II asks only whether established physical processes admit an event class capable of producing it under one coherent set of initial conditions.

## 2. Language Firewall: Entrance, Exit, and Middle Mountain

*The labels describe the pattern first. We do not get to smuggle the mechanism into the words.*

The phrase *entrance wound* is retained as the historical reconstruction label for the Antarctic domain, but Paper II does not begin by assuming that a coherent projectile physically opened a tunnel into Earth.

Likewise, *exit wound* is separated into two meanings:

1. **Exit-domain response:** the Arctic domain is the far-side or antipodal expression of the same event, potentially produced by focused stress, seismic waves, deformation, excavation, or other globally coupled processes.
2. **Literal material exit:** significant projectile or target material physically traverses a planetary-scale path and emerges from the far side.

The second statement is much stronger and is not granted merely because the first survives.

The *Middle Mountain* is also a geometric label before it is a mechanical one. Paper II must not assume central rebound, equatorial bulging, toroidal flow, or any other process simply because one could place it beneath the observed feature. The mechanism must produce the Middle Mountain response from independently specified physics.

# 3. What Counts as an Event Class

*We are not choosing one detailed impact story yet. We are sorting the physically different ways a large collision could couple the three domains.*

Three nested classes are considered.

## 3.1 Class A: Primary Impact with Antipodal Response

A large impact deposits energy and momentum near the Antarctic domain. Shock and seismic energy propagate through and around the planet. Because a spherical body focuses body and surface waves toward the antipode, the opposite hemisphere can experience enhanced stress and displacement. Antipodal disruption following large impacts has been studied for the Moon, Mercury, and Earth. [3–6]

Class A makes the weakest commitment. It requires no projectile to cross the entire planet. It is therefore the first physical comparison model for the Antarctic–Arctic pair.

## 3.2 Class B: Deep-Coupled Giant Impact

A sufficiently energetic collision can produce extensive shock heating, melting, excavation, mantle motion, and whole-planet redistribution while the target remains gravitationally bound. Giant-impact simulations and scaling studies occupy multiple regimes between simple accretion and catastrophic disruption, including erosion and hit-and-run outcomes. [14, 27–29] Large impacts can also generate extensive melt and long-lived thermal reorganization without requiring total dispersal of the target. [15, 35, 37]

Class B asks whether such deep coupling can produce not only a far-side response but also a robust intermediate response compatible with the inherited Middle Mountain domain.

## 3.3 Class C: Penetrating or Trans-Earth Material Transfer

Class C is the literal interpretation of an entrance and an exit: substantial material maintains a coherent or quasi-coherent directed transfer through a large fraction of Earth's interior and produces a far-side excavation or ejection response.

This is the strongest class and carries the largest burden. It must satisfy all Class-A and Class-B requirements plus an explicit penetration, deceleration, fragmentation, phase-change, and far-side mass-transfer calculation. Those processes are standard outputs of shock-physics and giant-impact calculations, but their simultaneous occurrence in a Day Zero trans-Earth trajectory has not been demonstrated. [13, 15, 29, 33] The old developmental Day Zero work explored this kind of description, but the canonical rebuild does not inherit it as established mechanics.

## 4. First-Principles Constraints

*Whatever the event was, it cannot bargain with conservation laws. Mass, momentum, energy, gravity, and material response set the first boundaries.*

### 4.1 Mass and Momentum

Let the target Earth have mass $M_T$ and the impactor mass $M_I$. Let the relative impact speed be $v_I$. The impactor momentum in the target frame is

$$\mathbf{p}_I = M_I \mathbf{v}_I.$$

For a collision without external impulse over the short impact interval, total linear momentum is conserved. Any directed far-side response must therefore arise from redistribution of the initial system momentum and internal stresses; it cannot create a new momentum vector at the Arctic domain.

The kinetic energy available before impact is

$$E_I = \frac{1}{2} M_I v_I^2.$$

For planetary collisions, impact speed is naturally compared with the mutual escape velocity. Giant impacts in terrestrial-planet formation occupy multiple outcome regimes including merging, hit-and-run, erosion, disruption, and super-catastrophic disruption, with outcome controlled by velocity, impact angle, mass ratio, and material state. [11, 14, 26–29]

### 4.2 Minimal Collision Coordinates

*Before arguing about a particular impactor, we reduce the event to a few ordinary collision variables: how massive it is compared with Earth, how fast it arrives compared with mutual escape speed, and how directly it hits.*

Paper II does not need a preferred impactor to state the event-class problem. A compact parameterization is

$$\gamma = \frac{M_I}{M_T}, \qquad v_{\mathrm{esc}} = \sqrt{\frac{2G(M_T + M_I)}{R_T + R_I}}, \qquad \nu = \frac{v_I}{v_{\mathrm{esc}}},$$

where $\gamma$ is projectile-to-target mass ratio, $v_{\mathrm{esc}}$ is the mutual escape speed, and $\nu$ is the dimensionless impact speed. Impact geometry is carried by an angle $\alpha$ or equivalent normalized impact parameter $b$, while the target is represented by the chosen early-Earth state $\mathcal{S}_\oplus$.

These variables are standard bookkeeping for gravity-dominated planetary collisions. [11, 12, 14, 26–28] They do not tell us which collision occurred. They prevent a later calculation from hiding physically different events behind similar total energies. A low-mass, high-speed projectile and a high-mass, lower-speed projectile can carry comparable kinetic energy while coupling momentum, shock, melt, and angular momentum very differently.

The canonical event coordinate is therefore kept deliberately small:

$$\Pi_{\min} = \{\gamma, \nu, \alpha \text{ or } b, \mathcal{S}_\oplus\},$$

with composition or internal structure added only when a tested event class actually requires them. Paper II does not assign preferred values to these coordinates.

### 4.3 Specific Impact Energy and the Survival Coordinate

A raw impact energy is not, by itself, the cleanest way to compare collisions with different projectile–target mass ratios. Gravity-regime collision studies instead use a reduced-mass specific impact energy. Let

$$M_{\text{tot}} = M_T + M_I, \qquad \mu = \frac{M_T M_I}{M_{\text{tot}}},$$

and define

$$Q_R = \frac{\mu v_I^2}{2M_{\text{tot}}}.$$

The corresponding catastrophic-disruption scale is written $Q^*_{RD}$: the reduced-mass specific impact energy associated with dispersal of approximately half the total system mass in the gravity-dominated regime. [14, 26]

For Paper II, the useful survival coordinate is therefore

$$\Psi = \frac{Q_R}{Q^*_{RD}}.$$

This is not a universal one-number verdict because $Q^*_{RD}$ depends on mass ratio, impact angle, material state, and collision geometry. It is a bookkeeping coordinate that prevents the model from confusing "large total energy" with "planetary disruption." The Day Zero event must occupy a regime in which the three required responses can be generated while the largest remnant remains recognizably Earth.

Crucially, no optional redistribution mode gets to enlarge the allowed energy window by definition. Each candidate event is tested at a fixed physically admissible collision state. If a self-consistent calculation redistributes the disturbance while retaining the three-domain response and a coherent Earth, that is a result. If survival appears only after the event is weakened until one of the required responses disappears, the mechanism has not solved the Day Zero burden.

### 4.4 Energy Rather Than Prescribed Power

*We can estimate how much energy the collision carries before we know exactly how long the strongest coupling lasts. A power value would require that extra timescale assumption.*

Paper II therefore uses impact energy and reduced-mass specific impact energy as the primary energetic variables. If a later numerical model resolves a characteristic coupling interval $\tau_c$, an average coupled power can be reported as

$$P_c = \frac{E_c}{\tau_c},$$

where $E_c$ is the mechanically relevant coupled energy over that interval. No value of $\tau_c$ or $P_c$ is prescribed here. This avoids hiding an unearned contact-duration assumption inside an apparently precise power estimate. Time dependence is not ignored: whole-Earth propagation times are treated separately below, and a resolved hydrocode or continuum calculation may supply the coupling history directly. [2, 10, 39, 41]

## 4.5 Energy Partition

The available impact energy does not all perform one task. A bookkeeping relation is

$$E_I = E_{\text{shock}} + E_{\text{heat}} + E_{\text{melt}} + E_{\text{ejecta}} + E_{\text{deform}} + E_{\text{grav}} + E_{\text{other}},$$

where the terms represent energy partition into propagating stress waves, heating, melting or vaporization, ejecta, deformation, gravitational work, and other sinks. Impact-cratering and shock-physics literature demonstrates that these fractions vary strongly with event scale, geometry, target state, and velocity. [2, 9, 10, 15, 31–33, 39]

Paper II therefore does not assign a single global efficiency factor. Any later calculation that requires one must expose it explicitly. The survival question is deliberately broader than any one deformation topology: a viable solution must show where the coupled energy goes and still leave a coherent Earth.

## 4.6 Planetary Survival Window

A necessary Day Zero condition is

$$E_{\text{coupling,min}} < E_I < E_{\text{disrupt}},$$

where $E_{\text{coupling,min}}$ is the minimum energy necessary to generate the required three-domain response and $E_{\text{disrupt}}$ is the relevant catastrophic-disruption threshold for the actual mass ratio, impact speed, angle, and early-Earth state.

For scale only, the gravitational binding energy of a uniform-density Earth-like sphere is

$$U_\oplus \approx \frac{3GM_\oplus^2}{5R_\oplus} \approx 2.2 \times 10^{32}\ \text{J}.$$

This is a reference energy, *not* a universal disruption threshold. Modern gravity-regime collision scaling shows that catastrophic disruption depends on reduced-mass specific impact energy and collision geometry rather than a single fixed fraction of $U_\oplus$. [14, 26, 29, 30]

The Day Zero event must therefore lie in a non-empty interval: energetic enough to couple the required domains, but not so energetic that the target loses the planetary continuity required by the reconstruction.

## 4.7 Survival Is More Than Avoiding Total Dispersal

*A calculation does not pass merely because some large remnant is left over. It has to leave a recognizable Earth that can continue through the rest of planetary history.*

The catastrophic-disruption coordinate $\Psi$ is a useful outer boundary, but it is not by itself the Day Zero survival criterion. By definition, $Q^*_{RD}$ is tied to a largest remnant containing roughly half of the total colliding mass. [14,26] A result can therefore lie below formal catastrophic disruption and still leave a target too eroded, fragmented, or globally dispersed to satisfy the historical continuity assumed by ABC Sequencing.

A later numerical test should therefore record at minimum the largest-remnant fraction

$$f_{\rm LR} = \frac{M_{\rm LR}}{M_{\rm tot}},$$

along with whether that remnant remains a single gravitationally coherent planet after reaccretion and relaxation. Collision calculations show that largest-remnant mass, erosion, stripping, and gravitational reaccumulation can vary strongly even below complete dispersal. [27–30] Paper II does not prescribe a numerical cutoff for $f_{\rm LR}$ beyond the ordinary disruption benchmark. It adds the stronger qualitative requirement that the surviving body remain sufficiently Earth-like to carry forward the sequence inherited by Papers I and II.

No proposed redistribution mode receives credit merely for lowering a local peak stress. The post-event body must still satisfy the same whole-planet survival requirement.

### 4.8 Why the Survival Problem Is Planetary in Scale

The inherited developmental reconstruction treated the Antarctic entrance domain as an affected area of order $10^7$ km$^2$. This is a model-domain scale, not a literal measured diameter of East Antarctica. If represented only for geometric intuition as an equal-area circle,

$$D_{\rm eq} = 2\sqrt{\frac{A}{\pi}} \approx 3.6 \times 10^3 \text{ km},$$

which is roughly 0.28 of Earth's present diameter. The point is not the exact number; it is that the hypothesized primary disturbance is continent-scale rather than ordinary-crater scale. That makes planetary survival part of the mechanism burden from the beginning.

This geometric scale must not be read backward as an impactor diameter. In gravity-regime cratering and giant collisions, affected-zone size, transient-cavity size, projectile size, and final deformed region are different quantities whose relations depend on velocity, angle, gravity, material state, and collapse. [2,9,14,31,32,40] Paper II therefore uses the $\sim 0.28 D_\oplus$ value only to classify the hypothesized disturbance as planetary in scale.

### 4.9 Brief Toroidal Survival Observation

*At this scale, Earth has to redistribute an enormous disturbance and still remain one planet. The old torus idea is retained only as a short, testable possibility for how some of that deformation might circulate rather than concentrate as simple rupture.*

The unavoidable statement is that a surviving planet-scale collision must redistribute momentum and energy among shock, heat, phase change, ejecta, deformation, gravitational work, rotation, and internal motion. Impact and post-impact models independently demonstrate several such pathways. [14,32,33,37,42]

The developmental Day Zero work proposed a transient toroidal-like planetary response as one possible survival geometry for an extremely large but still sub-disruptive event. [1] Paper II keeps only that observation. Standard toroidal–poloidal decomposition provides ordinary mathematical language for separating circulating from radial/meridional components of spherical flow, but it does not imply a torus-shaped planet. [23, 24]

Paper II therefore does not prescribe toroidal mechanics or assign a toroidal energy fraction. If a physically self-consistent calculation naturally develops strong circumferential redistribution while retaining the required three domains and one coherent Earth, the result is worth recording. If it does not, the Day Zero event class must stand or fall on the remaining physics.

## 5. Required Mechanical Sequence

*The event has a simple job order: disturb the Antarctic side, move stress and deformation through the planet, produce a middle response, produce a far-side response, and still leave one Earth afterward.*

Paper II does not need a detailed movie of Hadean Earth. It does need a causal order that every viable event class must respect. The minimum sequence is:

1. **Primary coupling.** Energy and momentum are deposited into the Antarctic-side domain strongly enough to create a planetary-scale primary disturbance.
2. **Global transmission and redistribution.** Stress, deformation, heat, phase change, gravity, and internal motion redistribute the disturbance through a self-gravitating body. Any large-scale circulation or redistribution mode must emerge naturally from the same calculation.
3. **Intermediate response.** The same evolving field produces a physically distinct Middle Mountain response rather than requiring a second unrelated event.
4. **Far-side response.** Propagating and globally redistributed energy produces an Arctic-domain response. Literal material exit is not required unless Class C is being tested.
5. **Rebinding and recovery.** The largest remnant remains Earth: gravitationally coherent, not catastrophically dispersed, and capable of relaxing from the transient event state into a long-lived planetary body.

This ordering is intentionally mechanism-neutral. It does not prescribe whether the dominant global pathway is seismic-wave interference, plastic deformation, melt flow, gravitational relaxation, rotation, large-scale circulation, or some combination. It simply prevents the paper from treating the three domains as three independent miracles. One event must do all five jobs in one continuous physical history.

## 6. Shock and Whole-Earth Propagation

*A giant impact does not need to drill a tunnel to affect the far side of a planet. Stress waves can cross the interior and surface waves can converge on the opposite side.*

Impact produces an initial shock that decays into elastic and inelastic wave fields as it propagates away from the source. Shock-wave structure and attenuation depend on material state, wave history,

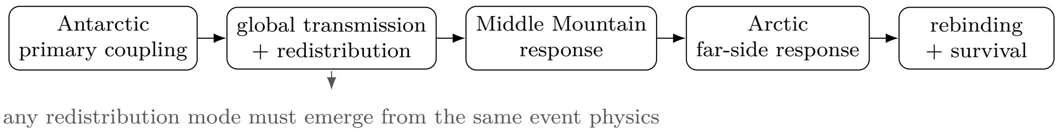


Figure 2: Minimum Paper-II causal sequence. The figure is a burden map, not a solved simulation. The same event must pass continuously from primary coupling through global redistribution to intermediate and far-side response while retaining a surviving Earth.

free-surface release, curvature, and internal boundaries. Near-surface compressive and rarefaction waves can interfere strongly, so flat-target intuition does not automatically extend to basin-scale events on a curved planet. [39, 40, 45] Standard reference Earth models show compressional-wave velocities of order several to more than 10 $\mathrm{km\,s^{-1}}$ through much of the mantle and core. [7, 8]

An order-of-magnitude diameter transit time is therefore

$$t_{\mathrm{cross}} \sim \frac{2R_{\oplus}}{v_P},$$

which for $v_P \sim 8$–$13\ \mathrm{km\,s^{-1}}$ gives roughly 16–27 minutes. This is not a Day Zero prediction; it demonstrates only that whole-Earth stress communication occurs on a timescale far shorter than geological relaxation.

Antipodal focusing is more subtle than a simple straight ray. Surface waves travel around the planet and converge geometrically, while body waves refract and reflect through a radially stratified interior. Three-dimensional heterogeneity, ellipticity, finite source size, and attenuation reduce idealized focusing. Planetary curvature and crust–mantle structure also alter the shock-pressure and interference field around very large basins. [40] In simulations of Chicxulub-scale forcing, realistic structure substantially reduces the largest point-source estimates while still leaving enhanced antipodal stresses and channelized high-stress regions. [6]

The existence of antipodal focusing therefore makes an Arctic far-side response physically admissible in principle. It does not demonstrate the magnitude, geometry, or morphology required by Day Zero.

## 7. The Antarctic Entrance Burden

*The Antarctic end has to behave like the primary side of the same event, not merely be a place we drew a circle around.*

For a common-cause impact interpretation, the Antarctic domain must be physically compatible with the primary energy-deposition side. Paper II does not require a pristine crater, particularly for a Hadean event, but it does require a plausible physical route from collision to large-scale modification.

Large impacts produce shock compression, excavation, melting, uplift, collapse, faulting, ejecta, and redistribution; the final morphology can differ substantially from the transient cavity. [2, 9, 31, 32, 34, 43, 44] Early-Earth impacts also occurred into a hotter and mechanically different target than the modern lithosphere. Magma-ocean and giant-impact studies therefore make the target thermal state a first-order uncertainty rather than a cosmetic detail. [15, 35–38]

Accordingly, Paper II does not equate a modern Antarctic depression, basin, or subglacial feature with an intact Hadean crater. Morphology alone is not diagnostic of impact origin; terrestrial impact confirmation ordinarily requires shock-metamorphic or meteoritic evidence capable of distinguishing impact from endogenic geology. [16, 17, 34] The physical claim in Paper II is weaker: the selected entrance domain must admit a primary-disturbance history consistent with the event-class parameters later used for the middle and far-side domains.

## 8. The Arctic Exit Burden

*The Arctic side must be produced by the same event. The first question is antipodal response; actual material punching out is a separate, harder claim.*

For Class A, the Arctic domain is tested against impact-generated antipodal focusing. A successful result would require a predicted far-side zone that is spatially and physically compatible with the inherited Paper-I exit domain under a realistic early-Earth interior model.

For Class B, the required response may include deeper deformation or redistribution beyond ordinary seismic shaking. Large-impact calculations show that thermal anomalies, melt, curvature-dependent shock fields, and subsequent thermo-mechanical adjustment can extend well beyond the transient cavity. [37, 40, 42] The calculation must still arise from the same impact parameters and interior model used at the entrance.

For Class C, a literal exit additionally requires a material-transfer calculation. At minimum, the model must track projectile and target deceleration, fragmentation, compression, melting/vaporization, entrainment, gravitational work, and the mass and velocity distribution that reaches the far-side domain. Those variables are ordinary outputs of hydrocodes and giant-impact calculations, but no published calculation is cited here as demonstrating a coherent Day Zero trans-Earth path. [13, 15, 29, 33, 41] No such calculation is assumed in the frozen Paper-II canon.

The naming rule is therefore:

> **Antipodal compatibility can support an exit-domain response. Only explicit material-transfer physics can support a literal exit.**

## 9. The Middle Mountain Burden

*Published impact models show that a large planetary impact can produce a real surface response between the source and the far side. Day Zero only asks whether the same event can produce the inherited Middle Mountain response without aiming the model at Hawai'i.*

The Middle Mountain remains the discriminating physical burden of Paper II.

A simple source–antipode picture might suggest that impact response should be strongest only at the impact site and the opposite side of the planet. That inference is too restrictive. Ni and Ahrens modeled free-surface motion on an idealized Earth-sized, compressible fluid sphere using a buried spherical pressure source and normal-mode summation. Their calculations produced a source response, a physically distinct intermediate response, and a strong antipodal response through interference between direct and quasi-surface waves. [18, 19]

This result matters because it establishes a limited but important point:

**A giant impact on a spherical planet is not mechanically restricted to a source response and an antipodal response. An intermediate surface response can arise from established wave physics.**

It does *not* establish the Day Zero Middle Mountain. The Ni–Ahrens model is intentionally idealized: a spherical compressible fluid planet, an equivalent buried pressure source, no intrinsic attenuation in the baseline calculation, and no realistic three-dimensional Hadean structure. [19] Paper II therefore does not treat the published position of the intermediate response as a frozen Day Zero coordinate or numerical target. Its value here is physical admissibility only.

## 9.1 The Localization Problem

If the source and target are perfectly axisymmetric, an intermediate response can remain a broad ring or band rather than identify one unique longitude. That is the mechanical form of the non-uniqueness problem already identified geometrically in Paper I.

A Day Zero mechanism therefore has a simple additional burden: if it claims a localized Middle Mountain rather than a broad planetary response, the localization must come from independently specified physics rather than from choosing parameters because they point toward Hawai'i.

## 9.2 Permitted Symmetry Breakers

Paper II permits symmetry breaking only when it comes from established physics that can be specified independently of the desired Hawai'i result.

**Impact obliquity.** Natural impacts are generally oblique. Experiments, observations, and hydrocode models show that impact angle can introduce strong downrange–uprange asymmetry in ejecta, shock strength, melting, vaporization, and projectile fate even when the final crater rim remains comparatively circular. [20, 21, 28] Obliquity is therefore a legitimate candidate for adding directional structure to the global response field. It is not a free aiming parameter: the required impact direction must be constrained before the Middle Mountain fit is scored.

**Inherited target structure.** Pre-existing cracks, faults, joints, blocks, porosity, damage state, and material heterogeneity are known to affect impact-wave attenuation, excavation, ejecta, faulting, and final crater morphology. Numerical and experimental scaling work explicitly shows that target properties can alter shock-wave decay, coupling efficiency, and cratering response. [22, 32, 44] A pre-existing susceptibility field may therefore amplify or redirect an otherwise broad response. But that field must be defined from evidence independent of modern Hawai'i; it cannot be invented because Hawai'i is where the hypothesis wants the response.

A useful abstract form is

$$R(\mathbf{x}; \Pi) = F_{\text{impact}}(\mathbf{x}; \Pi)\, S(\mathbf{x}),$$

where $F_{\text{impact}}$ is the impact-generated forcing and $S$ is an inherited susceptibility field. This expression is bookkeeping, not a constitutive law. The anti-circularity condition is that $S$ be independently specified before $R$ is compared with the Middle Mountain.

### 9.3 Prediction Order for the Middle Mountain

Oblique-impact hydrocode studies show that shock pressure and projectile/target response can become strongly asymmetric even when the final crater outline remains comparatively circular, so impact direction is a physically legitimate source of directional information. [20, 21] Target heterogeneity can also modify attenuation and crater response. [22]

Neither effect is automatically evidence for Day Zero. The prediction order must be:

1. specify the event parameters and any directional forcing from evidence independent of the Middle Mountain fit;
2. specify any inherited susceptibility field independently of modern Hawai'i;
3. calculate the resulting intermediate response field;
4. only then compare that response with the inherited Middle Mountain domain.

If the impact direction or susceptibility structure is selected because it points toward Hawai'i, the localization result is circular and receives no evidentiary credit.

### 9.4 Middle Mountain Mechanism Hierarchy

| Level | Recovered physics | Meaning | Canonical status |
|---|---|---|---|
| M0 | No intermediate response | Source and antipode respond, but no physically distinct middle response is generated. | Middle Mountain mechanism fails. |
| M1 | Broad intermediate response | A third response exists, as in the Ni–Ahrens idealized calculations, but remains geographically non-selective. | Physically admissible; not yet a Hawai'i prediction. |
| M2 | Directional intermediate lobe | Established source asymmetry, such as independently constrained obliquity, creates a preferred direction. | Stronger; direction must be predicted before Hawai'i comparison. |
| M3 | Independent local susceptibility | A pre-existing, independently mapped target structure amplifies the intermediate response. | Admissible only if susceptibility is not inferred from Hawai'i itself. |
| M4 | Directional forcing + independent susceptibility | A predicted impact response and independently specified susceptible structure converge on the inherited Middle Mountain domain. | Highest selectivity; highest parameter burden. |

Table 2: Middle Mountain mechanism hierarchy. Published impact-wave interference establishes that an intermediate response is physically possible; the remaining question is whether the inherited Middle Mountain can be produced without post hoc targeting.

Let $F(\mathbf{x};\Pi)$ denote the predicted global response field for event parameters $\Pi$, where $F$ may represent an admissible observable such as integrated deformation, surface velocity, uplift potential, cumulative stress, melt production, or another physically justified quantity. A successful event class must produce three independently testable conditions:

$$F(D_{\text{in}};\Pi) \geq T_{\text{in}}, \qquad F(D_{\text{mid}};\Pi) \geq T_{\text{mid}}, \qquad F(D_{\text{out}};\Pi) \geq T_{\text{out}},$$

with the same $\Pi$ and with thresholds $T_i$ defined before the final fit is scored.

### 9.5 Transient Response Is Not Modern Topography

*Paper II is not claiming that a giant impact instantly sculpted the modern mountain, basin, or ocean exactly as we see them today. It asks whether the event can seed the right large-scale response domains.*

A Hadean event and a modern landform are separated by billions of years of cooling, deformation, erosion, sedimentation, volcanism, plate motion, and later ABC sequence history. Terrestrial impact structures themselves can be modified, buried, deformed, or partly erased, while post-impact thermal anomalies can continue to relax long after crater formation. [17, 34, 42] Paper II therefore does not require a hydrocode output to resemble modern Antarctica, Mauna Kea, or the Arctic in photographic detail.

The mechanically relevant object is the *event-state response field*: where the primary disturbance is concentrated, where a distinct intermediate response develops, where the far-side response is enhanced, and whether the target survives. Paper I carries the separate burden of asking whether those domains remain recoverable in the present geometry after later history.

This distinction cuts both ways. A model does not fail merely because its immediate post-impact surface is unlike the modern landscape. But it also does not succeed merely because later geology could be imagined to transform an arbitrary response into the desired features. The event-state domains must first be predicted by the impact physics; later evolution may modify them, not create the original fit retroactively.

## 10. Minimum Outputs of a Viable Calculation

*A useful simulation does not need to recreate every detail of early Earth. It needs to report a small set of outputs that directly answer the Day Zero question.*

For each tested parameter set $\Pi$, Paper II needs only a compact physical output record:

$$\mathcal{Y}(\Pi) = \{f_{\text{LR}}, F_{\text{in}}, F_{\text{mid}}, F_{\text{out}}\},$$

where $f_{\text{LR}}$ records planetary survival and the three $F$ terms quantify the selected event-state response in the inherited domains. Additional flow or deformation diagnostics may be recorded when useful, but they are not pass conditions.

This output set deliberately omits lunar mass, orbiting debris, and final Earth–Moon angular momentum. Those belong to Paper III only after an Earth-event solution survives Paper II. It also omits any demand that a transient calculation reproduce modern topography. The purpose is to answer one bounded question with as few degrees of freedom as possible: does one collision state create all three required Earth responses while leaving one viable Earth?

## 11. Common-Cause Feasibility Window

*The event does not need one perfect set of numbers. It needs at least one physically allowed region where the same event makes all three responses and leaves Earth intact.*

Let $\Pi$ denote a complete event parameter set inside an event class $X$, and let $\Omega_X$ be the physically allowed parameter domain for that class before the Day Zero fit is scored. Define four pass/fail conditions:

$$S(\Pi) = \text{planet survives}, \qquad I(\Pi) = \text{entrance burden satisfied},$$

$$M(\Pi) = \text{Middle Mountain burden satisfied}, \qquad O(\Pi) = \text{Arctic/far-side burden satisfied}.$$

The common-cause feasibility window is

$$\mathcal{W}_X = \{\Pi \in \Omega_X : \ S(\Pi) \wedge I(\Pi) \wedge M(\Pi) \wedge O(\Pi)\}\,.$$

An event class is physically inadmissible if $\mathcal{W}_X$ is empty. It remains admissible if a non-empty region survives all four conditions under one parameter set. A broad, stable region is more persuasive than an isolated solution that appears only under fine tuning, but Paper II does not prescribe a numerical robustness threshold in advance.

No optional redistribution topology is included in the definition of $\mathcal{W}_X$. The feasibility window is earned only by the four required outcomes: survival, Antarctic response, Middle Mountain response, and Arctic response. Any additional global-flow pattern is interpreted afterward as a possible mechanism, not used beforehand as a condition for success.

## 12. Minimal Next Calculation

*The next calculation is deliberately small: ask whether one event can produce the entrance, middle, and far-side responses together, and stop there.*

Paper II does not require an enterprise-scale Earth reconstruction at this stage. Standard shock-physics hydrocodes and gravity-regime collision methods already provide the numerical language needed to track pressure, phase change, excavation, remnant mass, and reaccumulation. [14, 30, 41] The next useful computation is a bounded mechanism test that directly answers the common-cause question.

A minimal sequence is:

1. reproduce a benchmark in the Ni–Ahrens class of global-impact response models; [18, 19]
2. define a bounded parameter grid using only physically meaningful source variables such as source-zone size, depth, impact energy, and obliquity, without reference to Hawai'i;
3. for every parameter set, score planetary survival, the primary Antarctic response, the intermediate response, and the far-side response before selecting a preferred case;
4. identify the resulting common-cause feasibility window $\mathcal{W}_X$ rather than optimizing a single best-looking solution;

5. if localization is claimed, introduce at most one independently constrained symmetry breaker and calculate the resulting response before comparing it with Hawai'i;
6. within the surviving window, record any large-scale circulation or redistribution pattern that emerges spontaneously, including a toroidal-like component if present, without prescribing one in advance.

Ni and Ahrens found that the antipodal and intermediate responses are interference-controlled and sensitive to source-zone properties. [19] That makes a limited parameter sweep scientifically justified; it does not justify fitting an unrestricted model until Hawai'i appears.

The decisive output is therefore not a preferred angle. It is whether one physically coherent event model can reproduce the three inherited response domains under one parameter set.

## 13. Single-Parameter-Set Rule

*We do not get one impact for Antarctica, another set of numbers for Hawai'i, and a third story for the Arctic. One event has to do all three.*

The strongest anti-rescue rule in Paper II is parameter coherence. The feasibility window above is simply this rule written as a set rather than as a narrative requirement.

The minimal collision coordinates above provide the common parameter set,

$$\Pi_{\text{min}} = \{\gamma, \nu, \alpha \text{ or } b, \mathcal{S}_{\oplus}\},$$

with additional material parameters admitted only when independently required by the event class being tested.

The same parameter set must be propagated through all three domain predictions. A model fails the canonical test if, for example, the impact energy required to create the Antarctic response catastrophically disrupts Earth before the Arctic or middle response can be preserved, or if parameters needed to preserve the far-side response erase the middle response.

Parameter uncertainty is permitted. Parameter switching after each failed domain is not.

## 14. Comparison Event Classes

*The point is not to pick the most dramatic story. It is to see which level of physics is actually necessary.*

The hierarchy deliberately favors the least mechanically committed explanation capable of satisfying the inherited burdens. Class A is tested first. Class B is needed only if ordinary global impact response cannot supply the required coupled deformation while preserving Earth. Class C is needed only if independent evidence requires literal far-side material transfer. The literature supporting the physical ingredients summarized in Table 3 spans antipodal wave focusing, gravity-regime collision outcomes, shock melting, ejecta, and large-remnant survival. [6,14,26,29,32,33] The paper therefore escalates mechanics only when the weaker class fails for a specific physical reason.

| **Class** | **Minimum mechanism** | **What established physics already permits** | **Decisive Day Zero burden** |
|---|---|---|---|
| A | Primary impact + global wave interference | Source, intermediate, and antipodal surface-motion maxima are physically admissible in idealized spherical impact models. | Must generate a meaningful middle-domain response and, if localization is claimed, break axisymmetry without tuning. |
| B | Deep-coupled giant impact + global redistribution | Giant impacts can melt, excavate, deform, and redistribute planetary material without necessarily dispersing the target. | Needed only if Class A cannot supply the required middle amplitude, localization, or preserved deformation below disruption threshold. |
| C | Penetrating / trans-Earth material transfer | High-energy planetary collisions can produce extensive penetration, mixing, melt, vapor, and ejecta. | Must demonstrate actual far-side material transfer and survival; cannot infer transit from antipodal response. |
| Null | Unrelated inherited structures | Independent geological histories can create large features without a common event. | Must be beaten by a more selective common-cause prediction, not by narrative coherence alone. |

Table 3: Paper-II event-class hierarchy. The classes are nested in mechanical commitment, not in evidentiary status.

## 15. Quarantined Developmental Mechanics

*Older Day Zero mechanics do not become true because they were proposed first. Paper II keeps only the questions that can be retested without importing the old machinery.*

The February 2026 developmental Day Zero paper included a rotating viscoelastic Earth, explicit Coriolis terms, Maxwell-like rheology, dimensionless Reynolds/Rossby/Froude/Deborah regimes, a transient toroidal deformation hypothesis, lunar-disk energetics, and an Earth–Moon alternator concept. [1]

Those components are not canonical inputs to Paper II.

Specifically:

- no prescribed viscoelastic rotating-sphere mechanics;
- no prescribed toroidal deformation law, amplitude, or efficiency;
- no assumed tube-like body-force channel through Earth;
- no fixed Moon-forming energy band;
- no lunar mass-budget or orbital-capture condition;
- and no Earth–Moon alternator.

They may be revisited only if the canonical argument derives a need for them independently. The brief toroidal observation above does not restore the old toroidal model: it carries no fixed deformation function, required amplitude, or assumed efficiency. Paper II remains intentionally simple: conservation laws, impact/shock physics, global coupling, survival, and the three-domain response.

## 16. Falsification Architecture

*The mechanism has to be allowed to fail. These are the ways it can fail before we spend years making it prettier.*

Paper II is materially weakened or falsified if one or more of the following occurs under a properly specified model:

1. **No survival window.** The minimum event required to produce the three domains exceeds the applicable catastrophic-disruption regime.
2. **Rescue-mechanism failure.** Any optional redistribution mode, including a toroidal-like one, is required for survival only after being imposed or tuned rather than emerging from the same self-consistent event. That optional mechanism is then discarded without shielding the event class from the remaining tests.
3. **No Arctic coupling.** Realistic propagation and attenuation produce no far-side response compatible with the Arctic domain.
4. **No Middle Mountain.** Realistic models produce no intermediate response of sufficient magnitude compatible with the inherited Middle Mountain domain.

5. **Non-selective middle response.** The only viable intermediate response remains an axisymmetric ring or broad band and cannot be narrowed by independently constrained source or target physics.
6. **Wrong middle geometry.** The strongest independently predicted intermediate response systematically occurs away from the inherited Middle Mountain domain.
7. **Parameter incompatibility.** Entrance, middle, and exit each require mutually inconsistent impact masses, velocities, angles, or Earth states.
8. **Null-model dominance.** Independent or conventional geological histories explain the three domains substantially better without the shared-event assumptions.
9. **Transit failure.** For any literal Class-C exit claim, realistic penetration calculations show that material cannot reach or emerge from the far-side domain in the required state.

Failure of Class C does not automatically falsify Class A. Failure of Class A to explain the Middle Mountain does not automatically validate Class B. Each claim class is adjudicated at its own mechanical burden.

## 17. Permitted Paper-II Verdicts

*The answer does not have to be yes or no. We can say exactly how far the physics gets.*

**PHYSICALLY INADMISSIBLE** No parameter region survives basic conservation, propagation, and disruption constraints.

**PARTIALLY ADMISSIBLE** A primary-plus-antipodal event is physically possible, but the Middle Mountain or another required domain remains unexplained.

**UNRESOLVED** Available constraints are insufficient to determine whether a viable shared parameter region exists.

**SURVIVES EVENT-CLASS TEST** A class retains a physically coherent parameter region capable of generating all three required response domains without prohibited tuning.

**SUPPORTED BY PHYSICAL TEST** Independent numerical or experimental predictions reproduce a selective three-domain response materially better than comparison models.

The frozen Paper-II status is **PARTIALLY ADMISSIBLE / UNRESOLVED**. Established impact physics supports global and antipodal coupling, gravity-regime collision outcomes include large surviving remnants across a range of impact conditions, and published idealized calculations demonstrate that wave interference can also generate a physically distinct intermediate response. [6, 14, 18, 19, 26] The remaining burden is whether one independently constrained event model can reproduce the inherited Middle Mountain response together with the entrance and Arctic domains under the same parameter set.

## 18. What Paper II Does Not Establish

*Even if a viable event class exists, that still does not prove the Moon came from it or that the most dramatic version of the story happened.*

Paper II does not establish:

- the identity or composition of an impactor;
- an exact impact mass, speed, angle, or energy;
- a literal trans-Earth projectile path;
- a specific rheological model for the Hadean Earth;
- formation of the Moon;
- the amount or composition of orbiting ejecta;
- the present Earth–Moon angular-momentum budget;
- the Earth–Moon Alternator hypothesis;
- a solved or validated toroidal deformation mechanism;
- or the truth of the complete replacement-level Earth: Day Zero framework.

A physically admissible event class is a necessary bridge between geometry and a complete causal model. It is not the final model.

## 19. Advancement Condition

*Paper III only gets the Moon if Paper II first earns a physically coherent Earth event.*

Earth: Day Zero advances from Paper II to a Moon/ejecta consequence only if a single event class retains a coherent parameter region capable of satisfying the primary Antarctic response, the Middle Mountain response, the Arctic response, and planetary survival simultaneously.

The next-stage question is then separable:

> Given a surviving Earth-event parameter region, can the same event place the required mass, composition, energy, and angular momentum into bound circumterrestrial material consistent with lunar formation?

That is a Paper-III burden. It is intentionally not solved here.

**First make the Earth event work. Then ask what left Earth.**

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