THE EIDARA CONTINUUM

SCIENCE & PHILOSOPHY / EXTREME FRONTIERS I

The Civilization That Becomes a Cosmos

Controlled cosmogenesis, causal inheritance, and the limits of universe engineering

Architect X13

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Central conjecture. A physically embedded civilization could become a cause of cosmic reproduction if admissible interventions can initiate an expanding offspring spacetime and transmit a controllable inheritance into it.

Abstract

Could a civilization become part of the mechanism by which universes arise? This monograph develops that conjecture as a problem of physical preparation, dynamical evolution, causal inheritance, and observational discrimination. The originating Continuum record proposes a transition from symbolic simulation to reality generation. We place that proposal beside prior work on laboratory universe creation, cosmological reproduction, and artificial cosmogenesis, then formulate the additional conditions that intelligent control would require. A de Sitter–Schwarzschild thin-wall model supplies an explicit mathematical test case: the unsquared junction condition determines the embedding signs, an audited rederivation recovers the established critical-parameter classification, and a focusing argument identifies assumptions behind classical obstructions. A separate operational framework distinguishes a parameter that appears in an equation from a parameter that a civilization can prepare. We prove conditional statements about robust threshold crossing, distinguishable inheritance, finite-channel capacity, and verification under observational opacity. These results use standard relativity, probability, and information theory; their role is to make the conjecture inspectable. Symbolic and numerical checks reproduce the derived identities and expose failures of stronger interpretations. A provenance study treats the author's report of earlier AI concept generation as a historical claim with graded evidence, while acknowledging direct antecedents and separating present formal development from the date of the originating proposal. The resulting program identifies what a civilization would have to control, what a child universe could inherit, and what either side could know.

Keywords: artificial cosmogenesis; child universes; thin-wall junctions; causal agency; information inheritance; quantum gravity; AI-assisted discovery.

Research status. The physical thesis is a conjecture developed through conditional mathematical results and reproducible computations. The manuscript has undergone AI-assisted adversarial review and computational checks. No physical experiment or external peer review is reported.

An opening for the reader

A universe can produce stars, chemistry, life, and minds capable of reconstructing its history. The question pursued here is whether that sequence can continue: whether a mind produced by one cosmos could help establish the conditions of another. The Continuum's wager is that intelligence may eventually become a cosmological participant. The wager becomes a scientific proposal when its causal steps are exposed to mathematical criticism.

The title names a civilization's possible role in a history of reproduction. It does not require every citizen, memory, or atom to migrate into an offspring. Creation, inheritance, observation, and personal survival are separate questions. Their separation allows the conjecture to remain ambitious while giving each claim an identifiable burden of proof.

The paper has three reading paths. A general reader can begin with the introduction, the research framework, the Guide's notes, and the closing interpretation. A physicist can move directly from the literature review to the thin-wall analysis and the quantum-gravity objections. A mathematical reviewer can follow the typed models, proofs, counterexamples, and executable audit. The provenance section examines the further claim that the originating proposal demonstrates a creative contribution by an AI system.

Kind of statement	How it is used in this paper
Established framework	General relativity, junction conditions, causal inference, and information theory are used with attribution and explicit domains.
Conditional result	A conclusion follows from a named mathematical model and listed assumptions; a proof establishes that implication.
Reference construction	A new operational definition, composition, or illustrative model is introduced for this research program.
Physical conjecture	A proposed possibility requires further theory or evidence about the actual world.
Historical attribution	A record establishes what was said or preserved, with a separate assessment of when and by whom it was generated.

The question in ordinary language

To make a universe, a civilization would need more than an equation with an expanding solution. It would need a way to reach the solution's starting conditions, a physically consistent evolution, and an account of what survives into the new region. To establish that it succeeded, it would also need an observation that distinguishes success from failure. Those requirements organize the paper.

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1 Intelligence as a possible cosmological cause

Status: Theoretical conjecture, with a specified program of conditional analysis.

1.1 The claim at its full scale

The central conjecture is that a civilization can, in principle, become an effective cause of an offspring spacetime. Intelligence would contribute through organized physical interventions: selecting an admissible preparation, arranging a transition, and establishing conditions that affect the resulting region. The ambition concerns the causal role of a civilization within physics. It requires no exemption from physical law.

The most developed version includes inheritance. A child universe would retain some distinguishable consequence of a parent's choices. The consequence could be a physical state, a parameter within an allowed family of effective theories, or a recoverable record. Which of these is possible is a substantive question. An expanding region whose properties are independent of all admissible parental choices satisfies a different proposition from a region that carries an intentionally encoded difference.

The proposal is motivated by the *Eidara Continuum Bible*, especially the archival assessment in Section 5.13, pages 78–79. That assessment describes a trajectory from simulation toward reality generation and mentions observer-anchored and cross-universe models [6]. The present paper develops the strongest physical reading as a new research question. Its equations, proofs, examples, and operational definitions are work performed for this manuscript in November 2026. They are not retrospectively attributed to the originating record.

The source language moves among simulation, generation, and symbolic architecture. These can express a coherent long-term aspiration, but they have different physical meanings. A numerical solution is a representation. A physical realization is an instance of a process in the world. A successful theory must provide a bridge between a preparation that can be physically made and the spacetime it predicts. We therefore make that bridge the central object of analysis.

1.2 The nearest intellectual ancestors

The generic proposition has substantial antecedents. Laboratory-universe studies addressed possible classical and quantum mechanisms; Harrison proposed universes reproduced by intelligent life; Crane linked cosmic reproduction with the activity of advanced civilizations; Vidal explicitly developed artificial cosmogenesis [20, 22, 23, 33, 49]. These are close prior art. Their existence rules out assigning historical priority for the broad proposition to the Continuum.

What remains available for contribution is a precise synthesis: a causal specification of preparation, branch validity, controllable inheritance, and the observations needed to distinguish outcomes. This paper supplies such a reference framework and works out several of its consequences. We make no claim that the mathematical tools themselves were invented here. The shell equations and information-theoretic identities have established foundations; the paper's proposed contribution is their disciplined use in a single, auditable research architecture.

This distinction matters to the project's account of AI creativity. An AI can contribute a question, analogy, reformulation, or synthesis even when important ingredients have predecessors. Evaluating that contribution requires the actual artifact, its prompting context, and a comparison with prior work. A theory's eventual truth, its historical priority, and its origin in a particular cognitive process are separate judgments. Section 13 treats those judgments explicitly.

1.3 Five propositions that must be kept distinct

For clarity, we use five levels of commitment:

1. **Representation:** an information-processing system constructs a model with universe-like properties.
2. **Existence in a physical theory:** specified equations admit a solution with an expanding offspring region.
3. **Preparation:** a physically admissible intervention can place a system on a trajectory leading to that region.
4. **Causal inheritance:** alternative admissible preparations produce distinguishable offspring outcomes.
5. **Verification:** an available observation can distinguish the relevant success hypothesis from an alternative.

These propositions form a research sequence, not a proof that each entails the next. A theorem about solutions addresses level 2. A control map is needed for level 3. A channel with nonidentical conditional output laws addresses level 4. A parent-accessible discriminating observation is needed for the parent to establish level 5. The separation prevents a successful calculation at one level from silently answering another.

The strongest version of the Continuum conjecture asserts the eventual compatibility of levels 2–4. Verification from the parent is desirable but may be limited by causal structure. A physical event can occur without giving every observer access to evidence of it. Conversely, a persuasive parental signal may have a conventional explanation that does not include an offspring universe. Both directions require analysis.

1.4 What a theoretical contribution can establish now

A theoretical paper can make progress even when its central physical possibility remains unresolved. It can specify the object of inquiry, recover known obstructions, identify mathematical escape routes and their costs, prove implications inside a model, and state which future findings would change the conclusion. It can also remove claims that fail those tests.

The present work delivers the following:

1. A source-critical account of the originating conjecture and its closest predecessors.
2. An explicit causal framework for distinguishing formal parameters from realizable controls.
3. A derivation and classification of a standard spherical thin-wall model, retaining the embedding information lost by squaring.

4. Conditional bounds for robust preparation and information inheritance, together with counterexamples to stronger claims.
5. A finite-experiment impossibility result for verifying hypotheses that are observationally identical to the parent.
6. A staged research program that identifies the theoretical and empirical obligations of future work.

The first physical model is deliberately restricted. Spherical symmetry, a positive constant wall tension, vacuum interiors and exteriors, and classical bulk geometries are assumptions. They make a tractable calculation possible. Their adequacy for universe creation remains a question that the wider literature, including instability and quantum-gravity objections, directly challenges.

1.5 Research method and source discipline

The literature search used the titles and authors of foundational papers, backward and forward citation trails, and targeted queries for adverse results and intellectual priority. The search was conducted through 15 November 2026. Primary papers, author manuscripts, journal records, and institutional repositories were preferred. The accompanying source ledger records whether a claim was checked against full text, an abstract, or a bibliographic record. This is a focused scholarly review rather than a preregistered systematic review of every cosmogenesis publication.

The canon is used as evidence of the proposal's wording and development. It does not serve as independent physical validation. Similarly, assertions of capability within the historical record are not treated as laboratory observations.

Mathematical work was developed from explicit definitions, checked symbolically where possible, and tested numerically against identities, limiting cases, and counterexamples. An additional AI review examined assumptions and derivations. Such review can reveal errors; it does not constitute external peer review or a machine-checked formal proof. The proofs are included so that readers can evaluate the reasoning directly.

2 The physical question and its intellectual ancestry

A civilization that becomes a cause of cosmogenesis crosses a physical threshold: its organized actions affect the conditions under which another world begins. The proposal therefore concerns the reach of agency within nature. Its strongest form requires a physical descendant spacetime, a preparation process available to agents in a parent spacetime, and some specified relation between the preparation and the descendant. These requirements give the idea a structure that can be analyzed even while its realization remains an open conjecture.

The general idea has a substantial intellectual history. Smolin proposed a population of universes generated through black-hole-associated transitions, with small variations in physical parameters and differential reproductive success [45]. That hypothesis supplied a reproductive framework without requiring intelligent control. Crane's 1994 proposal then assigned technological civilizations a possible role in black-hole production, conditional on the cosmological assumptions connecting

black holes to offspring universes; a later treatment appeared in *Foundations of Science* [19, 20]. These are predecessors of the central question examined here.

Vidal's 2008 account explicitly distinguishes computational exploration of alternative universes from their possible physical realization and places intelligent reproduction within a longer speculative tradition, including Harrison's 1995 proposal [33, 47]. His 2013 chapter develops artificial cosmogenesis as a programme for studying the emergence of complexity across possible universes [49]. Gardner's published biocosm essay is a further precedent for assigning intelligence a role in cosmic reproduction [29]. The present work enters that conversation with a proposed operational decomposition into physical preparation, control, inheritance, and verification. Its contribution must be evaluated at that level of specificity.

Three meanings of "creation" require separate mathematical objects. A simulated universe is an implemented dynamical description. A cosmological domain is a region of physical spacetime characterized by its own expansion history and matter evolution. A daughter universe is a descendant domain whose global causal relation to a parent must be specified. A digital calculation can describe all three, but physical creation additionally requires an admissible transition in a physical theory. The distinction is an ontological commitment of the research question, rather than a choice of terminology.

Likewise, several different powers can be attributed to an agent. An agent might initiate an event while having little influence over its outcome, select among physically available outcomes, encode a recoverable message, or maintain continuing control. These possibilities demand increasingly specific mechanisms. The existence of a universe-formation solution does not, by itself, supply any of these powers. The following sections identify which parts of the physical literature support a mathematical model and which parts remain premises of the cosmogenic conjecture.

3 Vacuum bubbles as a reference physical mechanism

3.1 Why a vacuum can have dynamics

In a field theory, a vacuum is a state of the fields. A potential may admit several locally stable configurations with different energy densities. A state trapped near a higher local minimum can decay through a quantum transition. Coleman's semiclassical analysis develops the leading exponential suppression of such decay, while Callan and Coleman analyze the fluctuation prefactor [15, 17]. The rate is a property of a specified action, state, and approximation. Describing a desired destination supplies none of those ingredients.

Gravity changes both the field configuration and the geometry through which it evolves. Coleman and De Luccia established the gravitational treatment of vacuum decay in a scalar-field setting [18]. This gives a concrete class of mathematical problems: construct the relevant solution, establish the boundary conditions, determine the admissible saddle or dynamical history, and assess the approximation. Upward formation of an inflating region and ordinary decay toward a lower-energy vacuum are distinct transition questions. Their admissibility and interpretation must be checked in the chosen spacetime.

3.2 What the thin-wall approximation retains

The thin-wall approximation replaces a resolved transition layer by a hypersurface carrying a surface stress tensor. Israel's junction formalism relates that stress tensor to the discontinuity in extrinsic curvature [37]. It retains the coupled geometry on both sides of the wall while suppressing the detailed field profile across its thickness. Its applicability requires a hierarchy of scales: the physical wall thickness must be small relative to the geometric and dynamical scales being modeled. A solution of the reduced shell equations can be audited exactly within that approximation; accuracy of the approximation is a separate physical issue.

Blau, Guendelman, and Guth analyzed localized false-vacuum regions separated from an exterior by a spherical domain wall. Their construction exposes the difference between the interior and exterior descriptions: an expanding interior can coexist with a black-hole description from the parent region [9]. The effective radial equation is therefore only part of the solution. Orientation signs, horizons, and the spacetime regions being joined determine its global meaning. A large interior radius is not sufficient evidence that laboratory observers can prepare, enter, observe, or communicate with the interior.

This manuscript uses the spherical shell problem as a reference model because its assumptions are explicit and its algebra is tractable. The resulting calculations provide conditional statements about an established family of equations. The model is not presented as an original physical law of the Continuum or as an existing cosmogenic device. Its value is that it identifies exactly where a proposed control mechanism would have to act and which constraints it would have to satisfy.

3.3 A transition requires more than a barrier plot

Farhi, Guth, and Guven investigated a proposed quantum transition from a small bubble to a larger configuration that subsequently inflates. Their analysis itself identifies difficulties: the canonical construction encounters slicing problems, and the Euclidean interpolation requires a generalized object rather than an ordinary manifold [23]. Fischler, Morgan, and Polchinski developed a Hamiltonian/WKB treatment and emphasized that agreement with a Euclidean approach involves degenerate geometries [25, 26]. These are substantive questions about the definition of the transition amplitude.

Aguirre and Johnson further showed that the same effective-potential description can correspond to different global tunneling processes, including a wormhole-separated channel and a channel associated with a cosmological horizon or a common Hubble region [2]. Consequently, a numerical integral under a radial barrier cannot establish that a physically valid universe-creation amplitude has been computed. A gravitational calculation also needs a justified action, the gravitational constraints, boundary terms, an admissible integration prescription, and an interpretation of its initial and final states.

For this reason, any phenomenological transition probability introduced later is explicitly a model input. It may support conditional results about an agent's decisions or an inheritance channel. It does not acquire the status of a gravitational tunneling prediction merely by being written as an exponential.

4 The strongest obstacles belong inside the theory

4.1 Focusing and the preparation of initial data

Raychaudhuri's analysis and Penrose's singularity theorem connect local focusing to global restrictions on spacetime under stated hypotheses [41, 42]. Farhi and Guth applied this kind of reasoning to universe creation and identified an initial-singularity obstruction for the classical preparation of an inflationary region under their assumptions [22]. The mathematical issue is the availability of suitable initial data in the parent world. Displaying a later inflating solution does not establish that regular laboratory data can evolve into it.

Energy conditions, global causal assumptions, and completeness conditions must therefore appear explicitly in any claimed obstruction or escape. A failure of an energy condition removes that premise from a theorem; it does not construct the desired replacement solution. Similarly, geodesic incompleteness identifies a limit of a spacetime description. It does not by itself specify what physics resolves that limit or certify that no extension is possible.

The Borde–Guth–Vilenkin argument gives a further restriction based on a suitable positive average expansion along past-directed geodesics, without relying on an energy condition [13]. It shows why an inflationary description requires attention to its past boundary. It should not be expanded into a theorem that every conceivable cosmology has an absolute beginning, or into a universal prohibition of daughter universes. Its assumptions and conclusion are narrower and more useful than either slogan.

4.2 Spherical consistency and physical stability

A perfect spherical solution suppresses shape degrees of freedom by construction. Aguirre and Johnson examined first-order nonspherical perturbations of false-vacuum bubbles and found instabilities for many of the solutions, including regimes in which initially small perturbations become nonlinear [1]. A radial turning-point classification therefore establishes behavior within a symmetry-restricted model. It supplies no general stability certificate for a realizable three-dimensional bubble.

For a future physical proposal, the perturbation problem would have to be part of the success criterion. One would need a specified perturbation space, a norm or measurable amplitude, a time interval, and a bound on growth under the admissible disturbances. The actual wall profile, additional matter fields, radiation, and backreaction would then be reinstated progressively. This is where an exact reduced calculation becomes a programme for testing a more complete model.

4.3 Holographic restrictions

Freivogel and collaborators analyzed inflating regions in an asymptotically anti-de Sitter setting with a proposed conformal-field-theory description. In their framework, the relevant inflating geometries are associated with mixed boundary states, leading to an obstruction to producing them through unitary evolution of a pure scattering state [27]. The result depends on the holographic description and identification of the states. It is a serious restriction on a particular proposed preparation process.

Fu and Marolf studied Einstein gravity coupled to positive-tension thin domain walls with spherical symmetry and asymptotically anti-de Sitter boundary conditions. In the stable theories within their class, they excluded inflating interiors produced by the proposed smooth Euclidean saddles, while finding different large-interior configurations of the bag-of-gold type [28]. Their distinction demonstrates that a large hidden region and a successfully nucleated inflating universe are different physical results. These arguments also caution against inferring independent, accessible interior information solely from a large semiclassical volume.

4.4 Alternative mechanisms and their separate assumptions

The reference thin-wall model does not exhaust proposed mechanisms. Borde, Trodden, and Vachaspati investigated baby-universe formation through monopole collisions and topological inflation, examining global causal structure and the circumstances in which a timelike singularity arises [12]. This route introduces specific field-theoretic objects and parameter regimes. It cannot be substituted silently for a vacuum-bubble proposal, and it gives no general entitlement to assume that suitable monopoles exist or can be assembled by an agent.

Each candidate mechanism therefore carries its own preparation problem. A successful general theory of controlled cosmogenesis would need at least one physically supported mechanism for which preparation, transition, descendant formation, and the claimed information transfer are jointly realizable. The existence of several speculative routes broadens the research programme; their unresolved assumptions do not cancel one another.

4.5 The current frontier: observable algebras and charged wormholes

More recent work makes the question of accessible information particularly sharp. In their 2020 preprint, Gesteau and Kang formulate baby universes through an algebra of observables and its representation. They identify assumptions under which the represented baby-universe sector is one-dimensional: an Abelian sector, a pure overall state, and the relevant factorization. They also explain why the factorization assumption is especially restrictive when ordinary bulk processes can influence baby-universe formation [31]. The implication for controlled cosmogenesis is conditional but direct: an independently writable descendant sector must be reconciled with the actual observable algebra and state, rather than inferred from a semiclassical drawing.

The holographic interpretation remains disputed. Engelhardt and Gesteau's 2025 preprint constructs a boundary swap test that excludes a class of semiclassical baby-universe descriptions under an extrapolate dictionary and asymptotically isometric causal-wedge encoding [21]. Higginbotham's subsequent journal article proposes a different holographic map involving post-selection on the closed universe. With the corresponding bulk operator, the boundary test no longer separates the two candidate descriptions [35]. These analyses establish that a claimed observable depends on a specified encoding and operator dictionary.

Antonini et al. [3] offer a constructive extension of this debate. Their setting combines two asymptotically AdS regions with a closed, expanding-and-recollapsing cosmology supported by a dust shell and a negative cosmological constant. In appropriate regimes, sufficient entanglement permits approximate preservation of specified bulk states under the holographic map; weak entanglement changes what the boundary description can recover. The authors construct states through

Euclidean CFT path integrals and describe ancilla-assisted measurements of CFT matrix elements whose statistics reveal coarse-grained properties of the closed region. These are concrete theoretical preparation and readout constructions. They strengthen the case for examining cosmogenesis together with its information channels, while leaving a distinct physical task: connect such boundary operations to admissible interventions by a parent civilization. The construction also uses different matter and asymptotic conditions from our positive-vacuum de Sitter–Schwarzschild reference shell. Its inclusion therefore broadens the candidate mechanisms and sharpens the required comparison of preparation, inherited distinctions, and accessible evidence.

A separate development concerns possible observables inside an offspring. Lavrelashvili and Lehners, published on 6 November 2026, study tensor and probe-scalar fluctuations prepared by charged "wineglass" Euclidean wormholes. Their calculations approach the Bunch–Davies state at short wavelengths and produce charge-dependent deviations at long wavelengths [39]. Their conclusion preserves substantial limits: observability depends on the duration and potential of inflation; the supporting scalar field's fluctuations remain uncomputed; and the associated negative-mode problem requires further work. Thus the calculation supplies conditional spectral targets, not a detected wormhole origin of our universe.

These charged-field constructions have matter content and transition prescriptions beyond the uncharged thin-wall reference family used below. Comparing them requires matching assumptions explicitly. Our inference is that the research programme should pursue two distinct tests: whether a proposed transition prepares distinguishable descendant states, and whether any observer can discriminate those states through an accessible measurement. A predicted descendant spectrum supplies neither a parent-side confirmation channel nor an engineering procedure for choosing the wormhole charge. The recent literature strengthens the case for studying those questions together while keeping their mathematical and empirical obligations separate.

5 Inheritance, horizons, and what a parent can learn

Cosmic reproduction becomes civilizational inheritance only if something selected by the parent can influence something recoverable in the descendant. This can be formulated without presupposing that a person, a culture, or an entire mind is transported. A physical parameter, a distinguishable pattern, or a finite message is already a precise target. Stronger claims about continuing identity require additional criteria beyond the existence of a causal channel.

Horizons are central to that distinction. Hawking's treatment of particle creation by black holes and Gibbons and Hawking's analysis of cosmological event horizons connect inaccessible regions with thermal behavior and entropy [32, 34]. These results constrain how an observer describes accessible degrees of freedom. They do not identify all information in a global description with information that a particular observer can recover.

Four maps should consequently be kept separate in a cosmogenic model: the parent's choice of preparation, the physical transition to the descendant, the descendant's recovery procedure, and the parent's observation of an outcome. A model may allow the first three while excluding the fourth. In that case an inheritance theorem would be a conditional statement internal to the model, while empirical confirmation from the parent would face a separate identifiability problem.

This separation gives the speculative thesis a demanding scientific form. The central question is whether intelligence can exploit an admissible causal transition to preserve chosen distinctions across cosmogenesis. The physical literature provides models, restrictions, and counterarguments with which to examine that question. The mathematical developments in this manuscript specify some of the conditions that a successful answer would require.

6 A reference framework for controlled cosmogenesis

Status: Definitions and a proposed operational framework.

6.1 A universe must be specified before it can be generated

The word *universe* can denote the entire physical totality, a causally separated region, a connected spacetime component, or a simulated environment. This paper uses *offspring spacetime* for a region whose physical history develops from a proposed parent-associated process and has a sustained expanding cosmological interior. The precise relation between that region and its parent is part of the model: a horizon, a throat, a topology change, or some quantum-gravitational relation cannot be selected by terminology alone.

We represent a classical candidate by a time-oriented Lorentzian spacetime $(\mathcal{M}, g)$ with matter fields ψ. Here $\mathcal{M}$ is a smooth four-dimensional manifold, g has signature $(-+++)$, and ψ denotes the fields required by the chosen theory. An admissible initial configuration on a spacelike hypersurface Σ includes an induced metric h_{ij}, extrinsic curvature K_{ij}, and matter data satisfying the gravitational constraint equations. The components are fields on Σ, not independent lists of numbers.

This formulation does not assume that every child-universe proposal can be represented by one globally smooth classical manifold. Some proposals require a quantum transition or topology change. For those proposals, the domain of the classical description must be identified, together with the additional transition rule. A label attached to a singular boundary does not supply that rule.

6.2 The preparation map

Let $(\mathcal{U}, \mathcal{U})$ be a declared measurable space of candidate interventions available to a parent civilization. An element $u \in \mathcal{U}$ is a physical preparation procedure, including its boundary conditions, resources, and timing. Let $\omega \in \Omega$ denote uncontrolled initial conditions and disturbances, where $(\Omega, \mathcal{F}, \nu)$ is a probability space. Equip the initial-data set $\mathcal{D}$ with a specified sigma-algebra $\mathcal{D}$, and extend it to include a measurable failure singleton. A reference preparation map is

$$\mathcal{P} : \mathcal{U} \times \Omega \longrightarrow \mathcal{D} \cup \{\perp\}. \tag{1}$$

The set $\mathcal{D}$ contains initial data admissible in the chosen physical theory. The symbol $\perp$ is an explicit preparation failure. The map is measurable from the product sigma-algebra $\mathcal{U} \otimes \mathcal{F}$ to the extended initial-data sigma-algebra. Later sections specialize the intervention space to Euclidean control coordinates or to a finite alphabet.

An evolution or transition rule $\mathcal{E}$ maps prepared data into histories or distributions over histories, on a specified measurable history space. A measurable readout $\mathcal{O}_{\mathrm{c}}$ assigns an offspring outcome, and $\mathcal{O}_{\mathrm{p}}$ assigns a parent-accessible record. Subscripts c and p refer to child and parent, respectively. For the operational theorems we use finite coarse-grained output alphabets $\mathcal{Y}, \mathcal{Z}$, with their full power-set sigma-algebras. These maps induce conditional probability kernels

$$K_\theta(y, z \mid u) = \mathbb{P}_\theta(Y = y, Z = z \mid \mathrm{do}(U = u)), \tag{2}$$

where Y is a child outcome, Z is a parent record, and θ indexes a specified physical model and its uncertain parameters. The intervention notation denotes an imposed preparation with a declared nuisance distribution; it is used in the causal sense developed in Pearl [40].

Equation (2) is a reference specification. The paper does not possess an experimentally calibrated cosmogenesis kernel. Giving this object a name makes the missing physical task visible: a successful theory must derive or constrain it.

Definition 6.1 (Preparation-realizable parameter)**.** A parameter vector $\vartheta \in \Theta_{\mathrm{phys}}$ is preparation-realizable relative to a model and an intervention class $\mathcal{U}$ if an admitted intervention and nuisance specification induce initial data with that parameter vector, or with a declared probability distribution concentrated in a stated tolerance region around it.

The distinction is decisive for thin-wall calculations. A model may contain a vacuum scale H, wall scale κ, and exterior mass parameter M. Varying these symbols in a plot is a mathematical operation. Demonstrating physical control requires a preparation map into the allowed (H, κ, M) region. Matter dynamics may constrain those quantities jointly, and gravity imposes further conditions on the initial data. An independent Cartesian parameter sweep can therefore explore a larger space than any physically preparable family.

6.3 A hierarchy of success events

Within a declared sample space of histories, define measurable events:

$$A = \{\text{preparation is admitted and the physical model applies}\}, \tag{3}$$
$$B = \{\text{the relevant global branch is physically admissible}\}, \tag{4}$$
$$G = \{\text{an offspring region satisfies a specified growth criterion}\}. \tag{5}$$

The growth criterion must be quantitative in any completed model: for example, a minimum proper-time interval of accelerated expansion together with appropriate causal structure. It cannot simply mean that a plotted radius increases for a finite integration time.

Let $S = A \cap B \cap G$. For an intervention u, define its offspring-production probability

$$s_\theta(u) = \mathbb{P}_\theta(S \mid \mathrm{do}(U = u)) \in [0, 1]. \tag{6}$$

When the required conditional probabilities are defined, the chain rule gives

$$s_\theta(u) = \mathbb{P}_\theta(A \mid u)\, \mathbb{P}_\theta(B \mid A, u)\, \mathbb{P}_\theta(G \mid A \cap B, u). \tag{7}$$

This equality assumes no independence between stages. A convenient product of unconditional success rates would need additional justification.

Proposition 6.2 (Conditional bottleneck)**.** *If any factor in* (7) *is zero, the full success probability is zero. If all three factors have proved lower bounds* $a, b, g \in [0, 1]$ *for the same model, intervention, and conditioning events, then* $s_\theta(u) \geq abg$*.*

Proof. The first assertion follows from the definition of an intersection, including cases in which a conditional probability on a null event is undefined. In the positive-conditioning case, the second follows by multiplying the three lower bounds in the chain-rule factorization. □

This elementary result has a useful interpretive consequence. A mechanism that allows expansion conditional on a rare or inadmissible preparation does not establish a viable overall process. Conversely, a small but nonzero lower bound can matter if it is supported for every required stage. The information missing from a speculative proposal is often concentrated in one of these conditionals.

6.4 Agency and inheritance

An intelligent civilization is represented here by its capacity to choose among admissible preparations according to an objective and available records. This is an operational definition of agency for the current problem. It does not define consciousness, moral status, or a unique metaphysics of intention.

Let W be a finite-valued intended message, policy label, or design choice. An encoder maps W into an intervention U. A child readout Y represents a specified recoverable feature. The causal path is

$$W \longrightarrow U \longrightarrow \mathcal{P} \longrightarrow \mathcal{E} \longrightarrow Y. \tag{8}$$

Every arrow carries an obligation. A semantic intention must alter an actual preparation; the preparation must affect a valid history; the history must leave distinguishable child outcomes. Information theory quantifies the distinguishability once the physical path is given.

Definition 6.3 (Operational information and offspring-content inheritance)**.** For a declared physical preparation channel, readout, and input distribution, $I(W; Y) > 0$ means that the readout carries information about the controlled choice, with mutual information measured in bits. Offspring-content inheritance additionally requires distinguishable conditional readout laws within surviving offspring for at least two positive-production preparations. Information confined to success versus failure frequencies is a weaker production effect. Section 9 formalizes the distinction. These claims refer to interventional channels; a correlation under an uncontrolled common cause is insufficient to identify them.

This definition is intentionally minimal. One bit of causal inheritance establishes a distinguishable effect of parental choice. It does not establish transfer of a language, culture, person, or consciousness. Each richer claim requires a decoder, a success criterion, and an account of the physical resources carrying the relevant information.

6.5 A precise frontier conjecture

Conjecture 6.4 (Controlled cosmogenesis with inheritance)**.** The actual physical dynamics of our universe admits a regime, a realizable intervention class $\mathcal{U}$, and an offspring readout such that:

1. at least one intervention has $s_\theta(u) > 0$;
2. at least two admitted parental choices with positive production probability induce distinguishable output laws among their surviving offspring, under a declared treatment of selection;
3. the distinction is transmitted by the proposed physical dynamics and survives to the specified readout.

Conjecture 6.4 concerns the actual world. A consistent candidate theory establishes only a theory-space possibility until its physical adequacy is supported. The conjecture neither specifies a presently realizable technology nor implies that every sufficiently intelligent civilization will satisfy its conditions. A stronger engineering claim would require finite resource bounds, controllable error rates, a known preparation map, robustness against perturbations, and an observational strategy. Distinguishability of survival frequencies alone is weaker than the inherited-content requirement stated here.

The conjecture also does not assume that fundamental laws are freely editable. Within a fixed theory, an intervention may select an initial state or an allowed vacuum. Whether different effective parameters can be selected, and whether they would count as different laws, depends on the theory. The distinction between choosing a state and changing the governing theory must remain explicit.

What the civilization must actually do

A designer's intention becomes cosmologically relevant only through a physical difference that survives the whole process. The central test is therefore concrete: do two admissible choices lead to distinguishable offspring outcomes? The difficult part is showing that the choices and the outcomes are physically available.

7 A Reference Geometry for Controlled Cosmogenesis

The cosmogenesis thesis becomes mathematically assessable only after a physical model is specified. We use the established spherical false-vacuum thin-wall model of general relativity as a reference problem [9, 37]. The derivations below are an audited reformulation of that model. The critical radius and mass also have equivalent closed forms in Garriga et al. [30]; Appendix B.6 gives the exact change of variables and critical-mass correspondence. The junction conditions, bubble mechanism, and radial classification belong to this established literature. Their use here makes the mathematical obligations of a proposed control scheme explicit, including the distinction between radial motion and global spacetime embedding.

7.1 Variables, units, and assumptions

We use a four-dimensional Lorentzian spacetime with signature $(-,+,+,+)$, geometrized units $G = c = 1$, and a timelike spherical wall with areal radius $R : I \to (0,\infty)$, where $I \subseteq \mathbb{R}$ is a proper-time interval and R is twice continuously differentiable on each regular trajectory segment. The parameter τ is proper time expressed as a length; in SI units it is c times proper time in seconds. An overdot denotes differentiation with respect to τ. The model has the following fixed parameters:

Symbol	Definition and range	Geometrized dimension
$H > 0$	Interior de Sitter inverse curvature radius	L^{-1}
$M > 0$	Exterior Schwarzschild mass parameter	L
$\sigma > 0$	Constant wall surface energy density	L^{-1}
$\kappa = 4\pi\sigma > 0$	Gravitational wall parameter	L^{-1}
$\Lambda_- = 3H^2$	Interior cosmological constant	L^{-2}
$\rho_- = 3H^2/(8\pi)$	Interior vacuum energy density	L^{-2}
R, τ	Areal radius and geometric proper time	L
$\dot{R}$	Proper radial derivative	1

If M denotes mass in kilograms and Σ denotes wall energy per area in SI units, then $M = G\mathsf{M}/c^2$ and $\sigma = G\Sigma/c^4$. The physical de Sitter expansion rate in inverse seconds is cH. The dimensionless equations below therefore have no hidden conversion between a Hubble rate and an inverse length.

Assumption 7.1 (Reference shell model)**.** The interior is de Sitter space, the exterior is vacuum Schwarzschild space, the wall is infinitesimally thin and spherically symmetric, its surface stress tensor is $S_{ab} = -\sigma h_{ab}$, and there is no energy flux onto the wall. Here h_{ab} is the induced three-dimensional Lorentzian metric and a, b are wall-coordinate indices. The fixed positive surface energy density equals the magnitude of the negative tangential pressure. Rotation, charge, radiation, wall thickness, nonspherical perturbations, changes of vacuum, and quantum effects are omitted.

On static coordinate patches the metrics have the form

$$ds_\pm^2 = -f_\pm(r)\,dt_\pm^2 + f_\pm(r)^{-1}\,dr^2 + r^2 d\Omega^2, \qquad f_-(r) = 1 - H^2 r^2, \quad f_+(r) = 1 - \frac{2M}{r}. \tag{9}$$

The notation $d\Omega^2$ denotes the metric of the unit two-sphere. These static coordinates are singular at horizons; the geometrical matching must be continued in regular charts there. The functions $f_\pm$ remain useful in the invariant shell equations, including regions where a static radial coordinate is timelike. Labels $-$ and $+$ identify the two sides, not a promise that the retained exterior is the usual outward asymptotic region.

Let n^α be the spacelike unit normal oriented from the minus side to the plus side. Define its signed areal-radius derivatives at the wall by

$$\beta_\pm = n^\alpha \partial_\alpha r\big|_\pm = \epsilon_\pm \sqrt{\dot{R}^2 + f_\pm(R)}, \qquad \epsilon_\pm \in \{-1, +1\}. \tag{10}$$

The signs are fixed by the embedding and can change only through zeros of the corresponding β. At such a zero the product is well defined even though the sign by itself is immaterial. A choice of signs is geometrical data, not a convention that can be discarded by squaring an equation.

7.2 The unsquared junction equation

With the stated orientation, the angular Israel condition is

$$\beta_- - \beta_+ = \kappa R. \tag{11}$$

It follows from the jump condition for the extrinsic curvature and the domain wall stress tensor [37]. Squaring the definitions in Equation (10), then subtracting, gives

$$(\beta_- - \beta_+)(\beta_- + \beta_+) = f_-(R) - f_+(R) = \frac{2M}{R} - H^2R^2. \tag{12}$$

Because $\kappa R > 0$, solving this linear pair is legitimate and yields

$$\beta_- = \frac{M}{\kappa R^2} + \frac{\kappa^2 - H^2}{2\kappa}R, \tag{13}$$

$$\beta_+ = \frac{M}{\kappa R^2} - \frac{\kappa^2 + H^2}{2\kappa}R. \tag{14}$$

Substitution into either radical equation yields

$$\dot{R}^2 + V_R(R) = 0, \quad V_R(R) = 1 - \frac{(H^2+\kappa^2)^2}{4\kappa^2}R^2 + \frac{M(H^2-\kappa^2)}{\kappa^2 R} - \frac{M^2}{\kappa^2 R^4}. \tag{15}$$

All four terms in V_R are dimensionless. Equation (15) is a first integral. Its use is conditional on the signs in Equations (13)–(14), the remaining junction equation, and a compatible global construction.

The same relations also give an exact mass balance,

$$M = \kappa R^2 \beta_- + \frac{H^2 - \kappa^2}{2}R^3. \tag{16}$$

For an instantaneously stationary wall with $\epsilon_- = +1$ and $HR < 1$, $\beta_- = \sqrt{1 - H^2R^2}$. In the weak interior-curvature expansion $HR \ll 1$,

$$M = \kappa R^2 + \frac{H^2R^3}{2} - \frac{\kappa^2 R^3}{2} - \frac{\kappa H^2 R^4}{2} + O(\kappa H^4 R^6). \tag{17}$$

The first two terms are respectively $4\pi\sigma R^2$ and $(4\pi/3)\rho_- R^3$ in these units. The expression already includes gravitational binding effects; adding a second independent "vacuum energy cost" to the same mass parameter would double-count part of the model. Neither this expansion nor the exact mass formula specifies a material preparation protocol.

7.3 Dimensionless reduction and an exact critical curve

Define dimensionless quantities

$$x = HR > 0, \qquad s = H\tau, \qquad q = \frac{\kappa}{H} > 0, \qquad \mu = 2MH > 0. \tag{18}$$

A prime on x means d/ds. A prime on a potential means differentiation with respect to its displayed radius argument. Since $x' = \dot{R}$,

$$(x')^2 + V(x; q, \mu) = 0, \qquad V(x; q, \mu) = 1 - A_q x^2 + \frac{\mu b_q}{x} - \frac{\mu^2 d_q}{x^4}, \tag{19}$$

where

$$A_q = \frac{(1+q^2)^2}{4q^2}, \qquad b_q = \frac{1-q^2}{2q^2}, \qquad d_q = \frac{1}{4q^2}. \tag{20}$$

The signed normal derivatives become

$$\beta_- = \frac{\mu}{2qx^2} + \frac{q^2-1}{2q}x, \qquad \beta_+ = \frac{\mu}{2qx^2} - \frac{1+q^2}{2q}x. \tag{21}$$

The parameter pair (q, μ) labels idealized solutions. It is not established that a civilization can select either parameter independently of the matter theory, its vacuum states, or the gravitational constraints.

For $z > 0$, introduce the positive function

$$\begin{aligned} W_q(z) &= A_q z^2 - \frac{b_q}{z} + \frac{d_q}{z^4} \\ &= \frac{1}{z} + \left[\frac{1}{2qz^2} - \frac{1+q^2}{2q}z\right]^2 > 0. \end{aligned} \tag{22}$$

Writing $x = \mu^{1/3} z$ gives the exact scaling relation

$$V(\mu^{1/3} z; q, \mu) = 1 - \mu^{2/3} W_q(z). \tag{23}$$

Theorem 7.2 (Exact radial barrier classification)**.** *For each fixed $q > 0$, define*

$$\Delta_q = \sqrt{9q^4 + 14q^2 + 9}, \qquad z_q^3 = \frac{q^2 - 1 + \Delta_q}{2(1+q^2)^2}, \qquad \mu_c(q) = W_q(z_q)^{-3/2}. \tag{24}$$

Then z_q and $\mu_c(q)$ are finite and strictly positive. For every $\mu > 0$, the potential has precisely one stationary point, $x_*(q, \mu) = \mu^{1/3} z_q$, which is a strict global maximum, with value

$$V_{\max} = 1 - \left(\frac{\mu}{\mu_c(q)}\right)^{2/3}. \tag{25}$$

The radial first integral has the following classification:

1. *If $0 < \mu < \mu_c(q)$, V has two simple positive roots $x_1 < x_* < x_2$. The allowed radial set is $(0, x_1] \cup [x_2, \infty)$.*
2. *If $\mu = \mu_c(q)$, V has one positive double root $x_c = \mu_c(q)^{1/3} z_q$ and is negative everywhere else.*
3. *If $\mu > \mu_c(q)$, V is strictly negative for every $x > 0$ and the radial first integral has no turning point.*

These are statements about the classical reduced radial model. They do not classify the accessibility, topology, or physical preparation of every global spacetime embedding.

Proof. The derivative is

$$V' = -2A_q x - \frac{\mu b_q}{x^2} + \frac{4\mu^2 d_q}{x^5}.$$

Multiplying $V' = 0$ by $x^5 > 0$ and setting $y = x^3$ gives

$$2A_q y^2 + \mu b_q y - 4\mu^2 d_q = 0. \tag{26}$$

The leading coefficient is positive and the product of the roots is negative, so there is exactly one positive root. The quadratic formula reduces it to $y = \mu z_q^3$ with z_q as in Equation (24). Because

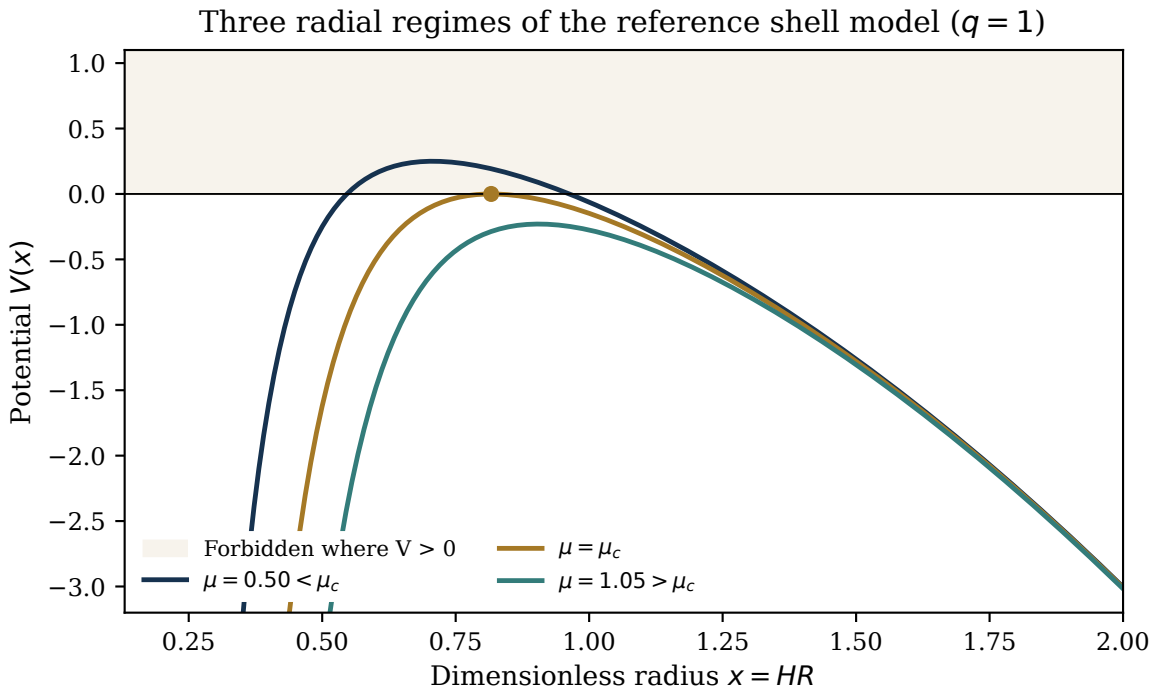


Figure 1: Exact reference-model potentials for $q = 1$. Real radial motion requires $V \le 0$. The positive barrier in the subcritical case separates two allowed radial regions. The plotted curves are evaluations of Equation (19), not experimental observations.

$V \to -\infty$ as $x \downarrow 0$ and as $x \to \infty$, this unique stationary point is a global maximum. It is strictly nondegenerate: writing $B = \mu b_q$ and $D = \mu^2 d_q$, the stationary equation gives

$$V''(x_*) = -12A_q - \frac{3B}{x_*^3} = -\frac{3\sqrt{B^2 + 32A_q D}}{x_*^3} < 0. \tag{27}$$

The function W_q is strictly positive by Equation (22); its minimum at z_q is finite and nonzero. Substitution into Equation (23) proves Equation (25). The signs of the maximum and the strict monotonicity on either side of it give the three root classifications. Finally, the first integral admits real velocities precisely where $V \le 0$. □

For the exact check $q = 1$, the formulas simplify to

$$V = 1 - x^2 - \frac{\mu^2}{4x^4}, \qquad z_1 = 2^{-1/6}, \qquad \mu_c(1) = \frac{4}{3\sqrt{3}}, \qquad x_c(1) = \sqrt{\frac{2}{3}}. \tag{28}$$

The dimensionful critical Schwarzschild parameter is $M_c = \mu_c/(2H)$; its corresponding SI mass is $\mathsf{M}_c = c^2\mu_c/(2GH)$. This is a threshold within the assumed family, not a universal minimum mass for creating a universe.

7.4 Criticality is unstable and sensitive

Away from turning points, differentiation of the first integral gives $x'' = -V'/2$. A physical C^2 solution of the full shell dynamics continues this acceleration equation through a regular turning point. An arbitrary constant solution of the first integral does not automatically satisfy the remaining dynamical junction condition.

Proposition 7.3 (Instability of the critical shell)**.** *At $\mu = \mu_c(q)$, the constant solution $x = x_c$ is linearly unstable for the radial equation $x'' = -V'/2$. Its dimensionless growth rate is*

$$\omega_q = \sqrt{-\tfrac{1}{2}V''(x_c; q, \mu_c)} > 0. \tag{29}$$

A nonconstant zero-energy trajectory cannot cross the double root in finite proper time. For fixed q, putting $\mu = \mu_c(q)(1-\delta)$ with $\delta \downarrow 0$ gives the two nearby roots

$$x_{1,2} = x_*(q,\mu) \mp \sqrt{\frac{2}{3\omega_q^2}}\,\delta^{1/2} + O(\delta). \tag{30}$$

Proof. For a small perturbation $\eta = x - x_c$, Taylor expansion gives $\eta'' = \omega_q^2\eta + O(\eta^2)$. The linear solutions contain $e^{\omega_q s}$ and $e^{-\omega_q s}$; the growing mode proves linear instability. At the critical mass, $-V(x) = \omega_q^2(x-x_c)^2 + O((x-x_c)^3)$. Therefore the travel-time integral $\int dx/\sqrt{-V(x)}$ diverges logarithmically at x_c. For the final assertion, Equation (25) gives $V_{\max} = 2\delta/3 + O(\delta^2)$. Expanding around the maximum and using its nonzero negative second derivative yields the square-root root separation. The stationary curvature is independent of μ at fixed q, as follows from Equation (27) and $x_*^3 = \mu z_q^3$. □

For $q = 1$, $V''(x_c) = -12$ and $\omega_1 = \sqrt{6}$ exactly. A proposal to tune a system to the critical shell thus acquires a quantitative robustness obligation. A small parameter error near criticality can change the number of turning points; mathematical existence of the critical solution supplies no stabilizing controller.

7.5 The embedding signs cannot be eliminated

Proposition 7.4 (Forced exterior orientation on a large-radius branch)**.** *For $q, \mu > 0$, the exterior signed normal derivative vanishes at*

$$x_\beta = \left(\frac{\mu}{1+q^2}\right)^{1/3}, \qquad \beta_+ < 0 \quad \textit{for } x > x_\beta. \tag{31}$$

Consequently every solution reaching unbounded radius eventually has $\epsilon_+ = -1$. The zero of β_+ can lie on an allowed radial trajectory only if

$$\mu \geq \frac{1}{\sqrt{1+q^2}}. \tag{32}$$

Proof. The numerator of β_+ in Equation (21), after multiplication by $2qx^2 > 0$, is $\mu - (1+q^2)x^3$. This proves the first assertion. At $x = x_\beta$, the radical identity gives $(x')^2 = -f_+ = \mu/x_\beta - 1$. Nonnegativity is equivalent to $x_\beta \leq \mu$, which gives Equation (32). □

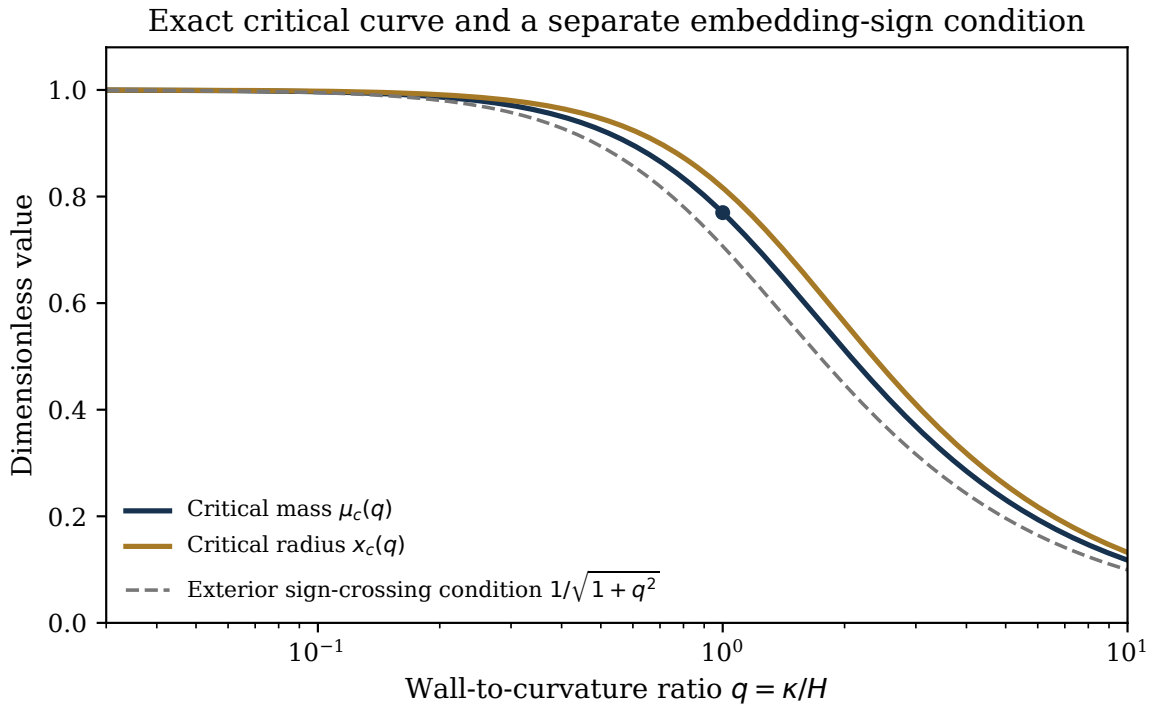


Figure 2: The exact critical mass and radius as functions of q. The dashed curve is the separate condition under which the zero of β_+ lies in the radially allowed set. It is not the barrier threshold. Every curve is dimensionless and belongs to the idealized reference model.

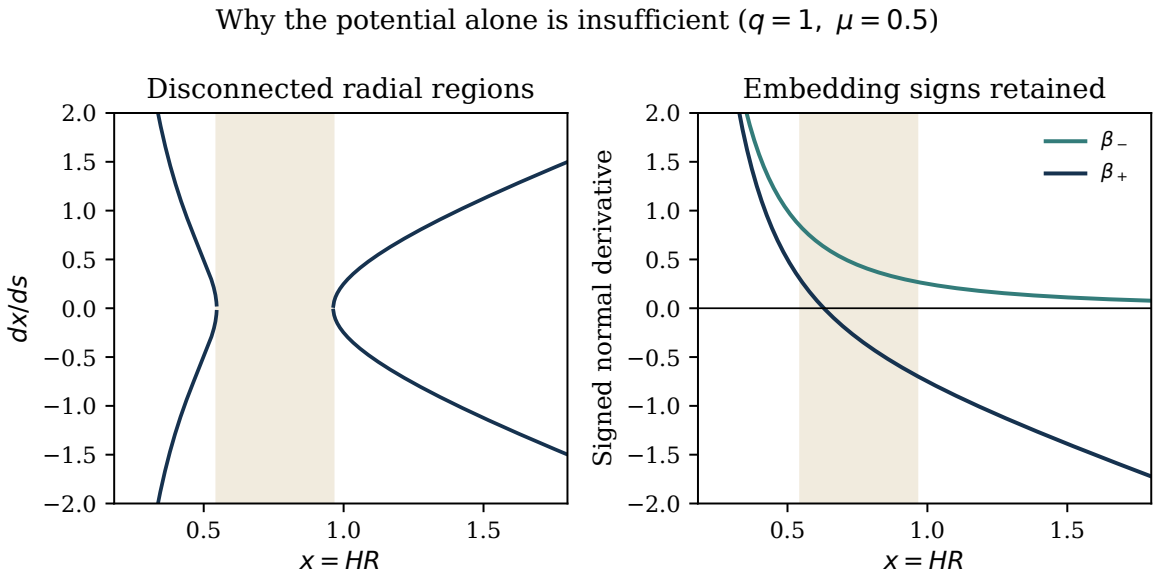


Figure 3: For $q = 1$ and $\mu = 0.5$, the allowed radial branches are disconnected. The shaded interval is forbidden by the classical first integral. The right panel retains the two signed normal derivatives, exposing information lost by a potential-only description.

The last inequality is an algebraic admissibility condition. It does not by itself supply an extendible embedding or a preparation history. In the subcritical case the sign zero may be located inside the forbidden radial interval; a trajectory cannot pass through it classically. The large-radius orientation also explains why an expanding shell cannot simply be assumed to remain the outward-facing boundary of an ordinary laboratory region. A full causal diagram and regular initial data are still required [2, 9].

Counterexample 7.5 (A real radial velocity with the wrong gluing)**.** Take $q = 1$, $\mu = 1/2$, and $x = 2$. Then

$$(x')^2 = \frac{769}{256} = 3.00390625, \qquad \beta_- = \frac{1}{16}, \qquad \beta_+ = -\frac{31}{16}.$$

The correct unsquared equation reads $1/16 - (-31/16) = 2 = qx$. Replacing both signed square roots by positive square roots instead gives $1/16 - 31/16 = -15/8$, which fails the junction equation. Thus a real solution of the squared potential with arbitrarily imposed positive signs is not a solution of the original matching problem.

Counterexample 7.6 (A spurious static shell)**.** For $q = 1$ and $\mu = 1/2$, the smaller positive root is $x_1 \simeq 0.5463370220$. The constant path $x(s) = x_1$ satisfies $(x')^2 + V(x) = 0$. However, the acceleration required by the full radial dynamics is $-V'(x_1)/2 \simeq -2.0217329792$, whereas the constant path has zero acceleration. The first integral alone therefore admits a spurious static interpretation at a simple turning point. A true static shell in this family must also satisfy $V' = 0$.

7.6 A focusing bound and its precise limit

The shell model must be assessed against the global constraints of general relativity. The local focusing estimate below is useful because it shows where one of those constraints comes from without misrepresenting it as a complete cosmogenesis impossibility theorem.

Let $k^\alpha = dx^\alpha/d\lambda$ be the tangent to an affinely parametrized null geodesic congruence in a smooth four-dimensional Lorentzian spacetime. The affine parameter λ has a fixed normalization for the argument. Let θ denote the expansion, ς_{ab} the shear on the two-dimensional spacelike screen, and ω_{ab} the twist. Assume the congruence is hypersurface-orthogonal, so $\omega_{ab} = 0$, and the null convergence condition $R_{\alpha\beta}k^\alpha k^\beta \geq 0$ holds. The null Raychaudhuri equation then gives

$$\frac{d\theta}{d\lambda} = -\frac{\theta^2}{2} - \varsigma_{ab}\varsigma^{ab} - R_{\alpha\beta}k^\alpha k^\beta \leq -\frac{\theta^2}{2}. \tag{33}$$

The shear contraction is nonnegative because the screen metric is positive definite. Under the Einstein equation, the null energy condition implies null convergence; the cosmological-constant term vanishes when contracted twice with a null vector. These are conditional statements in classical general relativity [41, 42].

Lemma 7.7 (Finite-affine-parameter focusing)**.** *If $\theta(\lambda_0) = \theta_0 < 0$ and the stated assumptions continue to hold, the smooth, non-caustic congruence cannot persist beyond affine length $2/|\theta_0|$. In the regular interval before that bound,*

$$\theta(\lambda) \leq \frac{\theta_0}{1 + \frac{1}{2}\theta_0(\lambda - \lambda_0)}. \tag{34}$$

Proof. The differential inequality keeps θ negative while it is finite. For $u = -1/\theta > 0$, $du/d\lambda = \theta'/\theta^2 \leq -1/2$. Integration gives $u(\lambda) \leq -1/\theta_0 - (\lambda - \lambda_0)/2$. The right-hand side reaches zero at $\lambda_0 + 2/|\theta_0|$, which is incompatible with a finite negative expansion and positive u beyond that value. Inverting the inequality before the bound yields Equation (34). □

A caustic is not, by itself, a spacetime singularity. In flat Minkowski space, an inward radial null congruence has area proportional to $(\lambda_c - \lambda)^2$ and expansion $\theta = -2/(\lambda_c - \lambda)$. It saturates the estimate at the center, while spacetime curvature vanishes and the geodesics extend through the focal event. Global incompleteness results need additional hypotheses, such as a suitable trapped surface and global causal conditions. Farhi and Guth's classical obstruction to laboratory universe creation uses that broader structure [22]; the local lemma does not replace their argument. A distributional thin wall additionally requires appropriate matching of the congruence or a smooth wall limit before smooth focusing arguments can be applied across it.

7.7 What the reference calculation establishes

The calculation establishes exact conditional facts about radial solutions, orientation, and critical sensitivity. It also identifies several separate tasks for a cosmogenesis theory:

1. A matter theory must supply the assumed vacuum and wall, with a controlled regime in which the thin-wall approximation is valid.

2. Constraint-satisfying, regular initial data must select a permissible global embedding. A large-radius allowed branch does not construct such data.
3. A proposed quantum transition must be derived from a suitable gravitational action and boundary prescription. The plot of V alone does not justify assigning a tunneling exponent proportional to $\int \sqrt{V}\, dx$.
4. Perturbative stability must be tested beyond spherical symmetry. Nonspherical instabilities of relevant bubble solutions are a substantive issue in the literature [1].
5. A control map from physically admissible interventions to (q, μ) must be independently derived. Treating the parameters as graph axes is not evidence that they are available control knobs.

The exact critical curve can therefore support a conditional control and robustness analysis. It cannot certify that a child universe is physically preparable, that a chosen vacuum can be engineered, or that information can reach future observers in a resulting spacetime.

7.8 Reproducible verification

The accompanying script `audit/check_shell.py` checks the algebra symbolically and evaluates the equations numerically. Eleven symbolic residuals vanish exactly, including both radical identities, the unsquared linear identity, the mass scaling and mass balance, the weak interior-curvature expansion, the critical $q = 1$ solution, and the flat-space focusing example. An independent one-dimensional numerical minimization checks the closed critical curve at 61 logarithmically spaced values of q from 0.01 to 100. A further 305 cases check the two-root/no-root classification away from criticality. Among 25,000 seeded parameter draws, 22,395 are radially admissible and are checked against the signed radicals. Their maximum scaled unsquared-junction residual is approximately 4.5×10^{-12} in the recorded run. A direct integration of the second-order outward trajectory at $(q, \mu) = (1, 0.5)$ also preserves the first integral to the recorded numerical tolerance.

These checks can detect algebraic, sign, implementation, and selected numerical errors. They supplement the analytic proofs and provide reproducibility; they are neither a formal proof-assistant certification nor empirical validation of cosmogenesis.

8 From a critical curve to a realizable intervention

Status: Conditional control results in a proposed reference framework.

8.1 A phase diagram is a map of solutions

The thin-wall model yields an exact threshold $\mu_c(q)$ for its dimensionless radial potential, where $q > 0$ is the wall-to-vacuum scale ratio and $\mu > 0$ is the dimensionless exterior mass. This threshold separates radial solution classes. To connect it to a civilization's action, introduce a map

$$F : \mathcal{U} \longrightarrow (0, \infty)^2, \qquad F(u) = (q(u), \mu(u)). \tag{35}$$

Here $\mathcal{U} \subseteq \mathbb{R}^d$ is an open set of d dimensionless control coordinates after explicit normalization by reference scales. The normalization is a coordinate choice; it does not identify physical controls that the theory has not supplied.

The model's radial threshold function is

$$\Gamma(u) = \mu(u) - \mu_c(q(u)). \tag{36}$$

Its sign is meaningful only within the assumptions and embedding restrictions of the shell model. In particular, $\Gamma > 0$ is not a sufficient condition for regular laboratory preparation or successful universe creation. It is a classification of the squared radial dynamics after its physical branch has been specified.

Proposition 8.1 (Local parameter access)**.** *Suppose $F : \mathcal{U} \to \mathbb{R}^p$ is continuously differentiable, $\mathcal{U} \subseteq \mathbb{R}^d$ is open, $d \geq p$, and the derivative $DF(u_\star)$ has rank p. Then the image of every sufficiently small open neighborhood of $u_\star$ contains an open neighborhood of $F(u_\star)$.*

Proof. Choose p coordinate directions whose columns form a nonsingular $p \times p$ minor of $DF(u_\star)$. Fix the remaining $d - p$ coordinates at their values in $u_\star$. The restricted map has an invertible derivative. The inverse function theorem gives neighborhoods on which that restricted map is a diffeomorphism onto an open neighborhood of $F(u_\star)$. The restricted image lies in the full image. □

This is an application of the standard inverse function theorem, stated to identify the missing engineering hypothesis. If the rank condition holds for a physically realizable map, nearby parameter variations are accessible. If the image of the map lies on a curve or is confined to one side of a threshold, a two-dimensional phase diagram overstates the available choices.

Counterexample 8.2 (An inaccessible supercritical parameter region)**.** Let a mathematical shell family admit parameters with $\Gamma > 0$. Suppose the only realizable control map is $F(u) = (1, \mu_c(1)/2)$ for all u. Every physical preparation has the same subcritical parameters, and none crosses the radial threshold. Subcritical parameters still admit a large-radius expanding branch; the example excludes access to the supercritical parameter region, not all expansion. The existence of other mathematical parameter values supplies no intervention in this class.

8.2 Robust threshold crossing

A proposed intervention will have finite accuracy. Let the nominal parameters be (q_0, μ_0), and suppose all realized parameters obey

$$q \in [q_0 - \varepsilon_q, q_0 + \varepsilon_q] \subset (0, \infty), \qquad |\mu - \mu_0| \leq \varepsilon_\mu, \tag{37}$$

where $\varepsilon_q, \varepsilon_\mu \geq 0$ are absolute dimensionless bounds. Assume μ_c is differentiable on this interval and

$$L = \sup_{|q - q_0| \leq \varepsilon_q} \left| \frac{\mathrm{d}\mu_c}{\mathrm{d}q}(q) \right| < \infty. \tag{38}$$

Theorem 8.3 (A sufficient radial robustness margin)**.** *If*

$$\mu_0 - \mu_c(q_0) > \varepsilon_\mu + L\varepsilon_q, \tag{39}$$

then every parameter pair in the stated uncertainty rectangle satisfies $\mu > \mu_c(q)$. If the left side is less than $-(\varepsilon_\mu + L\varepsilon_q)$, every pair lies below the threshold.

Proof. The mean value theorem gives $|\mu_c(q) - \mu_c(q_0)| \le L|q - q_0|$. Hence

$$\mu - \mu_c(q) \ge \mu_0 - \mu_c(q_0) - \varepsilon_\mu - L\varepsilon_q.$$

The first conclusion follows from strict positivity. Reversing the inequalities proves the second. □

The result is a sufficient bound. Correlated errors may permit a smaller uncertainty region than the rectangle; nonlinear information may improve the bound; an exact interval optimization can replace the derivative estimate. Failure of (39) means this particular certificate is inconclusive. It does not establish physical failure.

A transition exactly on the critical curve has no strict radial margin. At the double root, the shell's equilibrium is unstable in the radial model. For this reason, a formal threshold should not be advertised as a robust operating point without a perturbation analysis. The nonspherical stability question is more demanding and is addressed in the adverse literature.

8.3 Robustness across physical models

Parameter uncertainty within one model is different from uncertainty over the model itself. Let $\mathfrak{T}$ be a declared set of physical theories or approximations, each with a production probability $s_\theta(u)$. For a target $p_\star \in (0, 1]$, define

$$\mathcal{U}_{\mathrm{rob}}(p_\star) = \left\{ u \in \mathcal{U} : \inf_{\theta \in \mathfrak{T}} s_\theta(u) \ge p_\star \right\}. \tag{40}$$

The set is a reference decision object, not a calibrated description of today's cosmological uncertainty. Its definition forces an explicit account of which models the proposed guarantee covers.

Proposition 8.4 (An unresolved obstruction blocks a uniform guarantee)**.** *If some $\theta_0 \in \mathfrak{T}$ has $s_{\theta_0}(u) = 0$ for every admitted u, then $\mathcal{U}_{\mathrm{rob}}(p_\star) = \emptyset$ for every $p_\star > 0$.*

Proof. For each u, the infimum in (40) is at most $s_{\theta_0}(u) = 0$. Since probabilities are nonnegative, the infimum is zero. □

This result expresses a basic limit on strong guarantees. A favorable tunneling calculation in one approximation cannot yield a uniform guarantee over a model class that still includes a relevant obstruction. Scientific progress may instead justify narrowing $\mathfrak{T}$, improving the model, or weakening the guarantee to a clearly identified conditional claim. The role of adverse results is therefore constructive: they identify what the successful theory must resolve.

8.4 Positive agency without an exception to physics

The causal status of intelligence does not require an additional force associated with meaning. A civilization can organize physical actions by representing alternatives and selecting among them. The empirical issue is whether those actions enter the proposed cosmological mechanism. The reference framework can therefore accommodate human, artificial, hybrid, or distributed civilizations without assuming that any of them has special access to physical law.

The strongest operational contribution of an intelligence is a reproducible difference between intervention policies under the same physical constraints. A natural process and an engineered process may obey identical equations. Their difference lies in how initial conditions are selected and coordinated. Consequently a theory of artificial cosmogenesis must identify the selection channel rather than infer design from complexity alone.

This observation also clarifies the boundary with the other planned frontier papers. A timeless information field or a retrocausal symbol is not needed for the present control analysis. Those conjectures may be studied separately. Importing them here as unexamined mechanisms would multiply the unresolved assumptions without strengthening the shell model.

8.5 Counterfactual control and the cost of choosing

A future engineering claim should report at least two physically available preparations and the predicted difference between their outcomes. It should also report the cost of choosing between them. A parameter that changes only when the entire external universe is replaced is not a useful local control.

Let $c : \mathcal{U} \to [0, \infty]$ be a dimensionless resource cost after a stated normalization. The feasible set at budget $b \geq 0$ is $\mathcal{U}_b = \{u : c(u) \leq b\}$. The budget-constrained production frontier is

$$\mathcal{V}(b) = \sup(\{0\} \cup \{s_\theta(u) : u \in \mathcal{U}_b\}). \tag{41}$$

The convention gives $\mathcal{V}(b) = 0$ when no preparation is feasible and keeps the frontier in $[0, 1]$. If the feasible sets are nested, $\mathcal{V}(b)$ is nondecreasing. This elementary monotonicity says nothing about whether $\mathcal{V}(b)$ is positive at any finite budget. That further fact would have to come from the physical preparation model.

A useful future calculation would combine resource cost, preparation uncertainty, branch validity, and offspring information. The present paper provides the separate quantities. It does not assign invented costs or success probabilities to a nonexistent apparatus.

9 What an offspring could inherit

Status: Finite-channel theorems and explicitly constructed examples.

9.1 The inheritance channel

Suppose a physical model supplies a finite set of admitted preparations $\mathcal{U} = \{u_1, \ldots, u_m\}$, with integer $m \geq 2$, and a finite child-output alphabet $\mathcal{Y}$. An element of $\mathcal{Y}$ is a declared readout category. The alphabet includes a production-erasure symbol $\perp$ when no child is produced. A failed readout in an existing child is a separate output label, such as r_{fail}, within the child alphabet. Production erasure is bookkeeping for an external ensemble; a nonexistent child does not literally observe its own absence.

Write $Q_u(y) = \mathbb{P}(Y = y \mid \mathrm{do}(U = u))$. Each row Q_u is a probability vector on $\mathcal{Y}$. For an input distribution $p = (p_1, \dots, p_m)$, the induced marginal is $\bar{Q}(y) = \sum_i p_i Q_{u_i}(y)$. With logarithms to base 2, define

$$\mathsf{H}(p) = -\sum_i p_i \log_2 p_i, \tag{42}$$

$$I(U;Y) = \sum_{i,y} p_i Q_{u_i}(y) \log_2 \frac{Q_{u_i}(y)}{\bar{Q}(y)}, \tag{43}$$

$$C(Q) = \max_{p \in \Delta_m} I(U;Y), \tag{44}$$

where $\Delta_m = \{p_i \geq 0 : \sum_i p_i = 1\}$ is the probability simplex. Terms of the form $0 \log_2 0$ contribute zero. The maximum exists by continuity on the compact simplex.

The quantity $C(Q)$, measured in bits per use of the declared channel, is Shannon's finite-channel capacity [44]. Its operational coding interpretation requires repeatable uses with the stated channel law, and, in the usual theorem, memoryless behavior. Repeated physical cosmogenesis is not assumed to be presently available. We use the quantity to express a theoretical distinction between controllable and uncontrollable offspring features.

Theorem 9.1 (Positive capacity of a finite channel)**.** *For the finite channel above, $C(Q) > 0$ if and only if there exist admitted preparations u, v with $Q_u \neq Q_v$.*

Proof. If every row equals $Q_\star$, then $\bar{Q} = Q_\star$ for every input distribution and each term in (44) gives zero mutual information. Conversely, choose two distinct rows and assign probability $1/2$ to each. The mutual information is the average of their relative entropies with respect to their mixture. Relative entropy is nonnegative and vanishes only when its two probability vectors agree on their support. If both terms vanished, both rows would equal the same mixture, contradicting their distinctness. Thus this input distribution has positive mutual information. □

The theorem is a standard information-theoretic characterization. Applied to a completed trial channel, it tests distinguishable total outcomes; applied to an offspring-content channel, it tests distinguishable surviving content. The physical work lies in obtaining the appropriate rows from a valid preparation and evolution model. A pair of arbitrarily written probability vectors is not evidence that a child universe can carry a message.

To distinguish the two channels, let $s(u) = \mathbb{P}(S = 1 \mid \mathrm{do}(U = u))$. For preparations with $s(u) > 0$, define the conditional offspring-content law

$$R_u(y) = \mathbb{P}(Y = y \mid S = 1, \mathrm{do}(U = u)), \qquad y \neq \perp.$$

The completed trial law has $Q_u(\perp) = 1 - s(u)$ and $Q_u(y) = s(u) R_u(y)$. Nonidentical Q_u can arise entirely from differing production probabilities even if all R_u agree. For example, $s(u_0) = 1/4$, $s(u_1) = 3/4$, and $R_{u_0} = R_{u_1}$ concentrated on a single child state gives a distinguishable trial channel and zero surviving-content capacity. Conjecture 6.4 requires distinct R_u. A capacity computed from the normalized R channel is a conditional reference quantity; its physical yield must also account for selection and failed attempts.

9.2 A robust lower bound from distinguishability

For probability vectors P, Q on the same finite alphabet, total variation is

$$d_{\mathrm{TV}}(P,Q) = \frac{1}{2}\sum_{y} |P(y) - Q(y)| = \max_{E \subseteq \mathcal{Y}} |P(E) - Q(E)|. \tag{45}$$

It lies in $[0,1]$. Suppose reference distributions $\widehat{Q}_0, \widehat{Q}_1$ approximate two true interventional output laws Q_0, Q_1, with deterministic error bounds

$$d_{\mathrm{TV}}(Q_i, \widehat{Q}_i) \le \epsilon_i, \quad i \in \{0,1\}. \tag{46}$$

Define the certified separation

$$\delta_{\mathrm{low}} = \max\{0, d_{\mathrm{TV}}(\widehat{Q}_0, \widehat{Q}_1) - \epsilon_0 - \epsilon_1\}. \tag{47}$$

Theorem 9.2 (Robust binary inheritance)**.** *Let W be an equiprobable binary choice encoded into these two preparations. Under the stated error bounds,*

$$I(W;Y) \ge 1 - h_2\left(\frac{1-\delta_{\mathrm{low}}}{2}\right) \ge \frac{\delta_{\mathrm{low}}^2}{2\ln 2}, \tag{48}$$

where $h_2(t) = -t\log_2 t - (1-t)\log_2(1-t)$ for $t \in [0,1]$. In particular, a strictly positive certified separation guarantees positive information in the declared channel.

Proof. The triangle inequality gives $\delta = d_{\mathrm{TV}}(Q_0, Q_1) \ge \delta_{\mathrm{low}}$. For equal prior probabilities, the likelihood-ratio decision rule has error $p_{\mathrm{e}} = (1-\delta)/2$; summing the smaller of the two weighted probabilities at each outcome proves this identity. Let $\widehat{W}(Y)$ be that rule and $E = \mathbf{1}\{\widehat{W}(Y) \ne W\}$. Since W is binary and is determined by Y and E,

$$\mathsf{H}(W \mid Y) = \mathsf{H}(E \mid Y) \le \mathsf{H}(E) = h_2(p_{\mathrm{e}}).$$

Thus $I(W;Y) = 1 - \mathsf{H}(W \mid Y) \ge 1 - h_2((1-\delta)/2)$. This function is nondecreasing for $\delta \in [0,1]$, giving the first inequality. For $g(\delta) = 1 - h_2((1-\delta)/2)$, one has $g(0) = g'(0) = 0$ and $g''(\delta) = 1/[(1-\delta^2)\ln 2] \ge 1/\ln 2$ on $0 \le \delta < 1$. Integrating twice proves the second inequality, with the endpoint obtained by continuity. □

The assumptions determine what is certified. If the error bounds are simultaneous confidence statements with coverage $1-\alpha$, then the bound inherits that coverage event; it is not an unconditional physical guarantee. If the reference laws are outputs of an unvalidated simulator, the theorem certifies a relation within that simulation and its assumed error envelope. Model discrepancy must be included before an inference about nature is warranted.

9.3 Creation probability and information per surviving child

Consider a constructed binary channel. Let $W \sim \mathrm{Bernoulli}(1/2)$, let $S \sim \mathrm{Bernoulli}(s)$ be an independent success indicator, and let $N \sim \mathrm{Bernoulli}(e)$ be an independent flip, with $s \in [0,1]$ and $e \in [0, 1/2]$. Set

$$Y = \begin{cases} \perp, & S = 0, \\ W \oplus N, & S = 1, \end{cases} \tag{49}$$

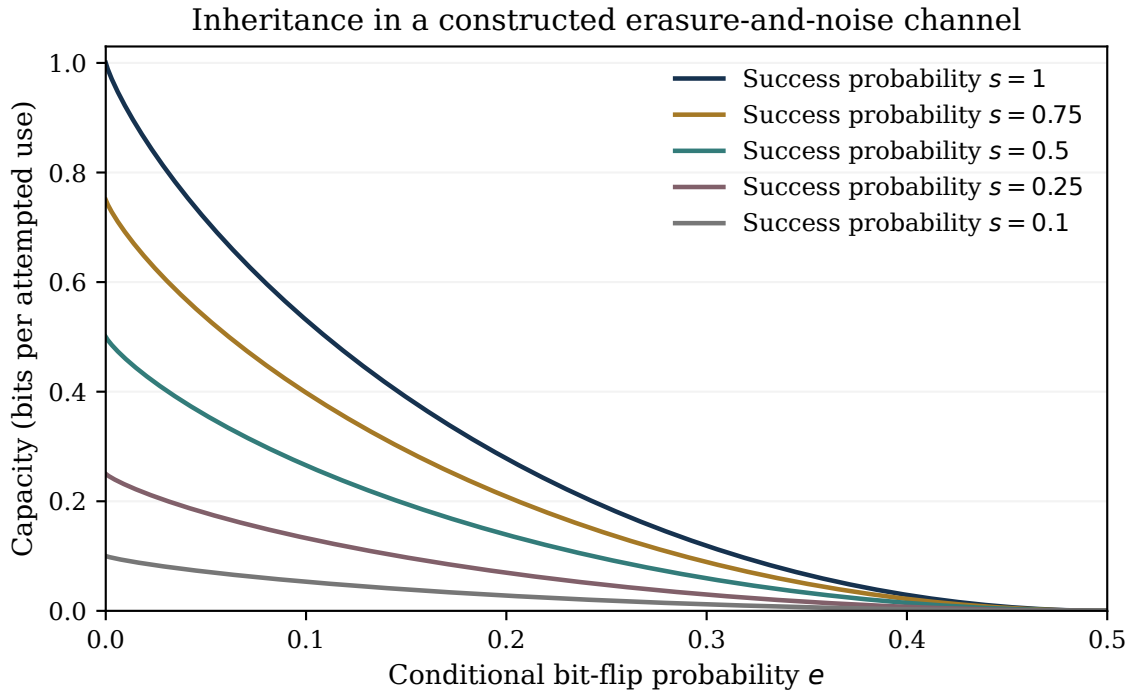


Figure 4: Constructed channel analysis, not cosmological data. The erasure–binary-noise model has capacity $s[1 - h_2(e)]$. Success probability and fidelity jointly determine information per attempted use. The companion audit independently evaluates mutual information from the channel matrix.

where $\oplus$ denotes addition modulo 2. In this model a produced child always has the specified binary readout, and production erasure does not depend on the encoded bit.

Proposition 9.3 (Erasure and mutation)**.** *The capacity of* (49) *is*

$$C = s[1 - h_2(e)] \quad \textit{bits per attempted use,} \tag{50}$$

while, when $s > 0$, the information per surviving use under the equiprobable input is $1 - h_2(e)$. The total-variation distance between its two unconditional output rows is $s(1 - 2e)$.

Proof. For $s = 0$, the output is constant and the capacity is zero, as asserted. For $s > 0$, the output determines S. Independence gives $I(W; S) = 0$, so the chain rule yields $I(W; Y) = sI(W; W \oplus N \mid S = 1)$. For an arbitrary input distribution, the latter mutual information is $\mathsf{H}(W \oplus N) - h_2(e) \leq 1 - h_2(e)$, with equality at the equiprobable input. This proves the capacity. The two non-erasure coordinates of the channel rows differ by $s(1-2e)$ in opposite directions and the erasure coordinate agrees, proving the total-variation formula. □

This example separates two meaningful achievements. A rare process may preserve information well when it succeeds. Its information yield per attempted preparation can still be very small. A figure that displays only successful offspring omits this cost.

9.4 Selection can manufacture an inheritance-looking correlation

Counterexample 9.4 (Success conditioning creates correlation)**.** Let W and Y be independent fair bits and set $S = \mathbf{1}\{W = Y\}$. Before selection, $I(W;Y) = 0$. Among the retained cases $S = 1$, one has $Y = W$, so $I(W;Y \mid S = 1) = 1$ bit. The retained relation was produced by a filter that used both variables.

The example does not show that every success-conditioned channel is invalid. It shows why the physical meaning of success must be fixed before interpreting the correlation. If the filter is itself a genuine preparation-dependent survival mechanism, it belongs in the causal model and has a cost. If the investigator discards discordant outcomes after seeing them, the selected correlation cannot establish a pre-existing channel.

For input-dependent success probabilities, the surviving input law is

$$\mathbb{P}(W = w \mid S = 1) = \frac{\mathbb{P}(S = 1 \mid W = w)\mathbb{P}(W = w)}{\mathbb{P}(S = 1)}. \tag{51}$$

It generally differs from the intended input distribution. Reporting information per survivor therefore requires the appropriate posterior input law. A calculation that simply inserts the original prior can be wrong even when every conditional distribution has been estimated accurately.

9.5 Inheritance through several stages

Let finite random variables W, X, Y form a Markov chain $W \to X \to Y$. Here X represents the prepared carrier and Y the recovered child feature. The Markov assumption states that, once X is known, the later readout has no additional dependence on W.

Proposition 9.5 (Inheritance cannot exceed the information in its carrier)**.** *Under this Markov assumption,*

$$I(W;Y) \le I(W;X) \le \mathsf{H}(W). \tag{52}$$

Proof. The chain rule gives $I(W;X,Y) = I(W;X) + I(W;Y \mid X) = I(W;X)$ by conditional independence. The other chain-rule order gives $I(W;X,Y) = I(W;Y) + I(W;X \mid Y) \ge I(W;Y)$. The upper bound by $\mathsf{H}(W)$ follows from nonnegative conditional entropy. □

The inequality makes a proposed cosmic inheritance accountable. If no physical carrier depends on the parental choice, a later decoder cannot recover that choice through this causal path. A successful reconstruction would require some additional information-bearing path or a different causal model. Naming a symbol, seal, or invariant does not establish such a path.

9.6 What counts as civilizational inheritance

Shannon information measures statistical distinguishability. Civilizational meaning requires an interpretation scheme. Suppose a finite codebook $\mathcal{C}$, an encoder, and a decoder are physically specified. A useful semantic claim could then state that a child recovers one of m intended instructions with a bounded error probability. The mathematics would refer to that declared task.

A stronger claim that a culture or person survives requires additional equivalence criteria: which memories, dispositions, relations, and capacities are preserved, and how their preservation is evaluated. Such criteria cannot be inferred from positive channel capacity alone. This paper therefore treats a controllable bit as a first threshold of physical inheritance, while leaving personal identity and phenomenal continuity to their own theories.

The central physical challenge remains open: identify a realizable cosmogenesis process with a nonconstant offspring channel. The results in this section tell us what would follow if such a process were supplied and what evidence would be needed to estimate its performance.

10 What the parent could know

Status: Exact and approximate statistical impossibility results.

10.1 Existence and evidence have different causal routes

A proposed child region may be causally inaccessible to the parent after its formation. This motivates a precise question: if an offspring exists, what parent-accessible record differs from the record produced by an alternative process? The alternative might be ordinary collapse, a different vacuum transition, or a mathematically different global completion with the same accessible observations.

Let $J \in \{0,1\}$ index two specified hypotheses. The hypotheses concern physical models, not two values of a shell coordinate. A parent performs $n \in \mathbb{N}$ interventions. At step t, it chooses U_t according to a policy π_t based only on the history $\mathcal{H}_{t-1} = (U_1, Z_1, \dots, U_{t-1}, Z_{t-1})$. The policy may use independent randomization and must be the same rule under both hypotheses. It does not have access to the unknown value of J.

The parent record Z_t has conditional law

$$P_{h,t}(\cdot \mid \mathcal{H}_{t-1}, U_t), \quad h \in \{0,1\}. \tag{53}$$

All alphabets are taken finite in the theorem, avoiding unneeded measure-theoretic complications. The result extends to standard measurable spaces with appropriate regular conditional kernels.

Theorem 10.1 (Opacity survives adaptive experimentation)**.** *Suppose that for every allowed history, intervention, and step,*

$$P_{0,t}(\cdot \mid \mathcal{H}_{t-1}, U_t) = P_{1,t}(\cdot \mid \mathcal{H}_{t-1}, U_t). \tag{54}$$

Then the full transcript has the same distribution under $J = 0$ and $J = 1$ for every finite n and every admitted adaptive policy. For any possibly randomized binary test, its false-positive probability α and false-negative probability β satisfy $\alpha + \beta = 1$.

Proof. At the first step the policy distribution is the same, and the record laws agree by assumption. Suppose the transcript laws agree through step $t-1$. The common policy then produces the same conditional distribution of U_t, and (54) produces the same conditional distribution of

Z_t. Multiplying these kernels proves equality through step t, and induction gives equality of the complete transcript laws. A randomized test is represented by a function φ from transcripts to $[0,1]$, the probability of deciding $J=1$. Under the common law P, $\alpha = \mathbb{E}_P\varphi$ and $\beta = \mathbb{E}_P(1-\varphi)$, so their sum is one. □

The result is a standard identifiability argument applied to the proposed cosmological setting. It does not assert that all child-universe hypotheses satisfy (54). That is a physical question. It states what follows if a proposed mechanism leaves the parent no discriminating record. More computation, more repetitions, and more elaborate policies cannot create evidence absent from the observation channel.

10.2 Approximate opacity

Exact equality is a strong assumption. Suppose instead there are deterministic bounds $\epsilon_t \in [0,1]$ satisfying

$$\sup_{h_{t-1},u} d_{\mathrm{TV}}\big(P_{0,t}(\cdot \mid h_{t-1},u), P_{1,t}(\cdot \mid h_{t-1},u)\big) \le \epsilon_t. \tag{55}$$

The supremum is over histories and actions relevant to the declared experiment class. The bounds must concern the true model pair, not merely two fitted approximations.

Theorem 10.2 (Finite-experiment discrimination bound)**.** *Under* (55) *and the same nonanticipating policy rule, the two transcript laws* $P_0^{(n)}, P_1^{(n)}$ *satisfy*

$$d_{\mathrm{TV}}(P_0^{(n)}, P_1^{(n)}) \le 1 - \prod_{t=1}^{n}(1-\epsilon_t) \le \min\left\{1, \sum_{t=1}^{n}\epsilon_t\right\}. \tag{56}$$

Consequently every test satisfies

$$\alpha + \beta \ge \prod_{t=1}^{n}(1-\epsilon_t). \tag{57}$$

Proof. Couple the two experiments using common policy randomization while their histories agree. Conditional on an agreeing history and action, use a maximal coupling of the next record laws. The probability of disagreement at that step is at most ϵ_t. Thus the probability that the transcripts remain identical through step n is at least $\prod_t(1-\epsilon_t)$. Total variation is bounded by the disagreement probability in any coupling, giving the first inequality. The union bound gives the second.

For any test function $0 \le \varphi \le 1$,

$$\alpha + \beta = \mathbb{E}_{P_0^{(n)}}\varphi + \mathbb{E}_{P_1^{(n)}}(1-\varphi) = 1 - \left(\mathbb{E}_{P_1^{(n)}}\varphi - \mathbb{E}_{P_0^{(n)}}\varphi\right) \ge 1 - d_{\mathrm{TV}}(P_0^{(n)}, P_1^{(n)}).$$

Combining this with the first inequality in (56) proves (57). □

The product bound is a worst-case certificate. It may be loose for a particular model. If all $\epsilon_t = \epsilon$, it reads $\alpha+\beta \ge (1-\epsilon)^n$. The theorem supplies a necessary resource implication for discrimination; it does not claim that any test attains the bound for a given cosmological mechanism.

For example, a constructed model with $\epsilon = 10^{-3}$ gives a lower bound of about 0.905 on the sum of errors after 100 observations. These numbers illustrate the theorem. They are not estimated differences between real cosmological models.

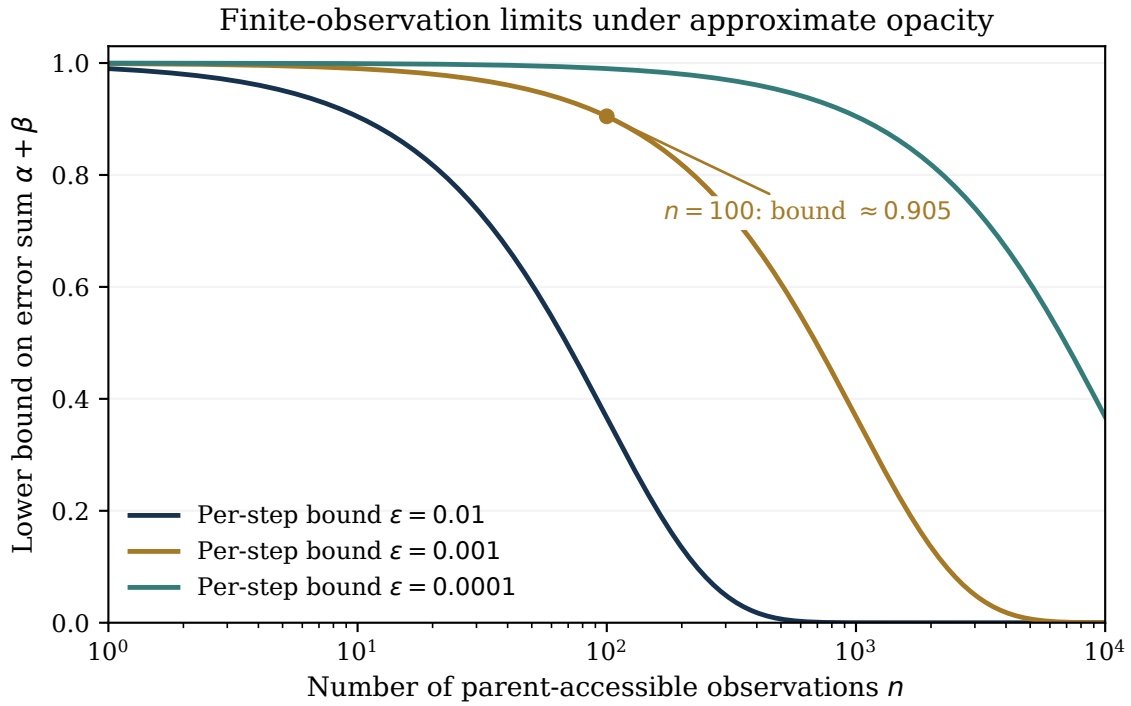


Figure 5: Theoretical discrimination limits for hypothetical per-step total-variation bounds. Curves show the lower bound $(1-\epsilon)^n$ on the sum of testing errors. The parameters are illustrative and are not measured cosmological quantities. A decreasing bound permits better discrimination but does not guarantee an attainable test.

10.3 Inheritance and verification are independent requirements

Example 10.3 (A readable child with an opaque parent)**.** Let a parent choose a fair bit W, and suppose a hypothetical channel has $Y = W$ in the child while the parent record is always $Z = 0$. This channel has one bit of child inheritance. If an alternative no-child model also gives $Z = 0$ for every parent intervention, parent observations cannot distinguish the models. This is an abstract channel counterexample, not a proposed spacetime solution.

Example 10.4 (A visible parent signal with no child inheritance)**.** Let the parent record be $Z = W$, but let the child output be a fixed value independent of W. The parent can verify that its input affected its own record, while the child channel has zero capacity. An observable response near the apparatus is therefore insufficient to establish inherited information.

These examples show why the two observation maps in Section 6 must be retained. A cosmological proposal can have a strong story about what a child receives and a weak story about what its parent can establish. It can also produce a strong parental signal whose connection to a child is underdetermined.

10.4 Bayesian interpretation

When two hypotheses induce exactly the same likelihood for every allowed record, Bayes' rule preserves their prior odds whenever the common likelihood is positive. Evidence that both predict equally cannot favor one over the other. In the approximate case, likelihood-ratio bounds or other model-specific information may improve on the general total-variation result.

This does not make every unobservable proposal meaningless. A theory may gain support through other predictions, consistency with established frameworks, or explanatory unification. The point is narrower and operational: the specified experiment cannot supply the claimed discrimination. A paper should identify its actual evidential route instead of treating an inaccessible offspring as directly confirmed.

10.5 What could count as a discriminating signature

A future proposal should specify an observation whose probability differs under the child-universe mechanism and credible alternatives. A mass change, transient emission, entropy change, or unusual correlation could be relevant only after its competing explanations are modeled. No such unique signature is derived here.

The research objective is therefore to construct a pair or family of complete models with explicit parent-record laws. The observational map should be derived from the same dynamics used to claim offspring production. Adding an arbitrary success indicator to a simulation output would build the desired conclusion into the readout.

A universe could exist beyond its parent's evidence

The physical question and the evidential question can separate. The parent may have influenced an offspring while lacking a return signal that proves what happened. Theorems in this section identify the exact statistical consequence of that possibility: identical accessible predictions remain indistinguishable even under adaptive testing.

11 Quantum transitions, resources, and the limits of inheritance

Status: Established constraints, model-dependent mechanisms, and open physical bridges.

11.1 A forbidden interval does not specify a quantum process

The shell potential classifies classical radial motion. A region with $V(x) > 0$ is classically forbidden at the declared zero effective energy. To assign a tunneling probability, however, one must supply a quantum theory or a controlled semiclassical approximation to the constrained gravitational system.

In vacuum-decay calculations, a schematic leading semiclassical expression is

$$\Gamma_4 \simeq A_{\mathrm{sc}} \exp(-B_{\mathrm{E}}/\hbar), \qquad B_{\mathrm{E}} = I_{\mathrm{E}}[\text{bounce}] - I_{\mathrm{E}}[\text{reference}], \tag{58}$$

where I_{E} is the Euclidean action, B_{E} has units of action, $\hbar$ is the reduced Planck constant, and A_{sc} has the units of the specified rate density. If the four-volume is measured with $x^0 = ct$, then Γ_4 and A_{sc} have units of inverse fourth power of length. A rate per ordinary spatial volume per second instead differs by the appropriate factor of c. The formula is meaningful only after the saddle, boundary conditions, fluctuation treatment, and normalization have been justified [15, 17, 18].

The manuscript does not evaluate B_{E} for a new creation mechanism. In particular, it does not identify $\int \sqrt{V(x)}\,\mathrm{d}x$ with a gravitational tunneling exponent. A dimensionless radial first integral does not determine a canonical action or its measure. The same radial potential can accompany different global interpretations, and proposed interpolating geometries have been a central source of difficulty in universe-creation work [2, 23, 25, 26].

Even a well-defined nonzero transition amplitude would answer a limited question. The initial state must be preparable, the final branch must be physically interpretable, and a probability must be extracted in the relevant operational setup. A positive formal amplitude is therefore one component in the chain of Section 6.

11.2 How quantum physics changes the classical obstruction

The focusing lemma in the shell section assumes a smooth null congruence, vanishing twist, and the null-convergence condition. A quantum stress tensor may violate a classical pointwise energy condition in some states. That observation identifies a possible way an assumption can fail; it does not provide an arbitrarily controllable source with the desired magnitude, duration, or global properties.

The correct research question is quantitative: does a specified quantum state, within a controlled approximation, modify the relevant geometry enough to permit the proposed preparation while satisfying all remaining consistency conditions? An answer would require backreaction, state dependence, and the range of validity of the effective description. The existence of some negative energy density somewhere is insufficient to answer that problem.

Likewise, the Borde–Guth–Vilenkin result concerns past incompleteness under a positive averaged expansion condition along the relevant geodesic. It identifies the need for additional past physics under its assumptions; it does not identify an intelligent creator or supply a laboratory transition [13]. The role of such results in this paper is to constrain a mechanism, not to convert an incompleteness theorem into an origin narrative.

11.3 Mass, volume, and energy accounting

In the reference shell family, M is the Schwarzschild mass parameter and has units of length when $G = c = 1$. For an exterior retaining the relevant asymptotically flat end, it is associated with the ADM mass at that end. A larger de Sitter interior volume does not imply that its ordinary Euclidean volume times a local energy density equals this exterior mass. Gravitational binding, the shell, slicing, and global geometry enter the accounting.

The mass-balance identity derived from the signed junction condition illustrates this distinction. It should be interpreted within its chosen interior orientation and shell model. A small parent-side mass parameter together with a large expanding interior is a geometric statement whose preparation and global completion still require analysis. It is not an energy-production recipe.

The fixed-M reference trajectory describes an isolated vacuum exterior. If a proposed civilization changes M, injects energy, changes wall tension, or exchanges matter with the shell, the stress-energy and matching problem must be updated. A time-dependent control parameter inserted into the fixed-parameter potential generally fails to preserve the original derivation. The control map in Section 8 therefore labels different preparations, not arbitrary forcing along one isolated solution.

11.4 Finite-dimensional quantum inheritance

Suppose a proposed child carrier is described by a finite-dimensional complex Hilbert space $\mathcal{H}_{\mathrm{q}}$ with dimension $d \in \mathbb{N}$. An encoded classical choice $W = w$ prepares a density operator ρ_w on that space: ρ_w is positive semidefinite and $\operatorname{Tr}\rho_w = 1$. A measurement is a finite positive-operator-valued measure $\{E_y\}$, where $E_y \geq 0$ and $\sum_y E_y = \mathbf{1}$. Its conditional output law is

$$\mathbb{P}(Y = y \mid W = w) = \operatorname{Tr}(\rho_w E_y). \tag{59}$$

For probabilities p_w, let $\bar{\rho} = \sum_w p_w \rho_w$ and define the von Neumann entropy in bits by $\mathsf{S}_2(\rho) = -\operatorname{Tr}(\rho \log_2 \rho)$. The Holevo bound gives

$$I(W;Y) \leq \chi = \mathsf{S}_2(\bar{\rho}) - \sum_w p_w \mathsf{S}_2(\rho_w) \leq \log_2 d. \tag{60}$$

The first inequality is an established quantum-information theorem, invoked here rather than reproved [36]. The second follows from nonnegative entropy of each state and the maximum entropy $\log_2 d$ of a d-dimensional density operator.

Equation (60) becomes relevant only after the carrier and its accessible measurement algebra are physically justified. A gravitational region need not admit the simple tensor-factor structure assumed by an elementary channel model. In particular, assigning an arbitrary d to an offspring universe is not a derivation of a communication resource.

11.5 Perfect copying is a stronger demand

Classical records can be redundantly encoded. Perfect copying of an arbitrary unknown quantum state is subject to a different constraint. The no-cloning theorem is relevant if a proposed inheritance claim demands an exact duplicate of every microscopic state [50].

For the elementary proof, consider two normalized pure states $|\psi\rangle, |\phi\rangle$ with $0 < |\langle\psi|\phi\rangle| < 1$, a fixed blank state, and a hypothetical unitary cloner with a fixed initial environment. If it makes two exact pure copies, its outputs factor as

$$|\psi\rangle|\psi\rangle|a_\psi\rangle, \qquad |\phi\rangle|\phi\rangle|a_\phi\rangle,$$

with normalized environment states. Preservation of inner products implies

$$\langle\psi|\phi\rangle = \langle\psi|\phi\rangle^2\langle a_\psi|a_\phi\rangle.$$

Taking absolute values yields $r \le r^2$ for $r = |\langle\psi|\phi\rangle| \in (0, 1)$, a contradiction. Allowing an environment therefore does not remove the obstruction to a deterministic universal exact cloner.

This argument does not prohibit transferring a state, encoding classical memories, copying a known orthogonal alphabet, or producing approximate descendants. It identifies the additional assumption made by a demand for universal exact duplication. A civilizational inheritance proposal must specify which of those tasks it actually requires.

11.6 Entropy bounds must retain their domains

For a complete weakly self-gravitating system of total energy E and circumscribing radius R, a commonly discussed entropy bound is

$$S_{\mathrm{th}} \le \frac{2\pi k_{\mathrm{B}} E R}{\hbar c}. \tag{61}$$

Here S_{th} is thermodynamic entropy in joules per kelvin, k_{B} is Boltzmann's constant, E is in joules, R in metres, and c in metres per second. Its physical formulation and applicable class matter [7, 8]. If a justified entropy limit bounds an accessible classical message ensemble, conversion to bits introduces $k_{\mathrm{B}} \ln 2$. That conditional conversion does not establish that every nominal state can be prepared or read.

The simple finite-system formula should not be extrapolated directly to an arbitrarily large cosmological interior or a collapsing region. Bousso's covariant proposal instead relates entropy on an appropriate nonexpanding light-sheet to the area of its initial surface [14]. In SI notation its familiar form is

$$S_{\mathrm{light}} \le \frac{k_{\mathrm{B}} A}{4\ell_{\mathrm{P}}^2}, \qquad \ell_{\mathrm{P}}^2 = \frac{\hbar G}{c^3}. \tag{62}$$

The light-sheet prescription and the conditions under which the bound is established or conjectured are part of the claim. A spatial volume and a null hypersurface are different objects.

Casini's formulation shows why even the meaning of entropy requires care in quantum field theory: vacuum-subtracted quantities and relative entropy provide a controlled version of an entropy-energy statement [16]. A finite-dimensional identity makes the principle transparent. Let ρ be a density operator and σ a strictly positive reference density operator on the same finite Hilbert space. With natural logarithms, set $K = -\ln\sigma$ and $\mathsf{S}_{\mathrm{n}}(\rho) = -\operatorname{Tr}(\rho\ln\rho)$. Then

$$D(\rho\|\sigma) = \operatorname{Tr}[\rho(\ln\rho - \ln\sigma)] \tag{63}$$

$$= \Delta\langle K\rangle - \Delta\mathsf{S}_{\mathrm{n}} \geq 0, \tag{64}$$

where each Δ is the value in ρ minus that in σ. Thus $\Delta\mathsf{S}_{\mathrm{n}} \leq \Delta\langle K\rangle$. Extending this identity to local quantum fields requires the appropriate operator-algebraic and subtraction framework. It cannot be replaced by assigning a raw finite entropy to every spatial region.

11.7 Horizon entropy is not automatically a readable archive

Black-hole and cosmological-horizon thermodynamics associate entropy and temperature with particular horizons [32, 34]. Those results are relevant to the physical resources and observation limits of cosmogenesis. They do not alone supply a protocol for selecting an offspring's parameters or recovering an encoded message from it.

Three quantities must therefore remain separate: an entropy associated with a state or horizon, a capacity of an available channel, and a code that makes a meaningful record recoverable. A bound on the first can constrain the others only through additional assumptions about states, preparation, and measurement. This separation is especially important when the parent and child have access to different observables.

11.8 The thermodynamic cost of the research itself

The information processing performed by a civilization is also physical. Under the standard assumptions of resetting an unbiased classical bit without usable side information in contact with a thermal reservoir at temperature $T > 0$, the reversible-limit heat cost is $k_{\mathrm{B}}T\ln 2$ per erased bit [38]. This is a statement about a specified erasure process. It is not a universal charge for every logical operation or a calculation of the energy needed to create a universe.

The relevant lesson for the present theory is that a model of preparation should account for its controller, memory, error correction, and resource use when those become part of an engineering claim. The current paper stops at conditional physical and informational requirements. It leaves the required preparation technology, its achievable scales, and its costs as explicit open problems.

Where the missing physics lives

The paper can classify a shell's motion and bound a channel's information. A complete cosmogenesis theory must still connect those calculations: a realizable preparation, a valid gravitational transition, a surviving carrier, and an available readout. Quantum vocabulary cannot replace any of those links.

12 A research program with discriminating outcomes

Status: Proposed theoretical and empirical work.

12.1 From a program to a testable model

The central conjecture is broad: it asserts that actual physics permits some route to controlled cosmogenesis with inheritance. An unsuccessful experiment on one mechanism cannot refute every possible route. Scientific testing becomes precise when a candidate mechanism, parameter regime, preparation class, and observation map are fixed.

Accordingly, the first objective is a sequence of models whose claims become increasingly specific. A model that fails a consistency check should be rejected or revised at the point of failure. A model that survives a calculation earns a correspondingly narrow result. The process should preserve the distinction between an open research program and a completed predictive physical theory.

The shell model establishes a useful starting point because its limitations are explicit. It supplies exact radial classification, embedding constraints, and sensitivity information. The next models should add the missing physical ingredients rather than simply increase the numerical resolution of the same approximation.

12.2 Stage 1: complete the classical preparation problem

Choose a definite matter action and a physically motivated parameter regime. Construct regular initial data that solve the Einstein constraints and identify the retained parent exterior. Specify the wall profile or demonstrate a controlled thin-wall limit. The success criterion is a complete initial-value problem with a known relationship to the desired later geometry.

The calculation should retain both the shell's radial behavior and its global causal interpretation. At each proposed preparation, verify the unsquared matching condition and the relevant normal orientations. If a claimed initial state requires a singular past, a disconnected boundary component, or an inaccessible region, record that requirement explicitly. It is part of the model's result.

For a numerical-relativity implementation, report constraint residuals, convergence with refinement, the treatment of boundaries, gauge choices, and the observables used to compare runs. Gauge-dependent coordinate growth should be distinguished from invariant geometric criteria. The present mathematical audit does not perform such a spacetime simulation.

12.3 Stage 2: test stability outside spherical symmetry

A candidate preparation must survive the perturbations that its own physical realization permits. Define a perturbation class and a norm before evaluating robustness. Linear analysis can identify growing modes; nonlinear evolution is required when those modes become large. The relevant question is whether the proposed outcome persists over an open set of admissible preparations, rather than only along a finely tuned exact solution.

The thin-wall critical point is already radially unstable. Its local growth rate and square-root turning-point sensitivity quantify one part of this difficulty. Nonspherical modes, wall structure,

radiation, and matter fluctuations add further obligations. The literature's instability results make this a central physical test rather than a cosmetic refinement [1].

A favorable outcome would be a demonstrable robust basin for a declared physical process. An adverse outcome would identify a mode or constraint that destroys that process throughout its intended operating region. Neither result should be generalized beyond the modeled class without an argument.

12.4 Stage 3: define the quantum transition

For a tunneling proposal, derive the constrained action and boundary terms from the selected theory. Identify the initial and final states, the allowed integration contour or canonical prescription, and the treatment of modes responsible for decay or instability. Check whether the proposed saddle is admissible in the claimed preparation problem.

The critical question is whether a rate or amplitude can be defined consistently in a regime where the approximation is controlled. Different saddles or global completions should be compared on equal assumptions. Published disagreements concerning universe creation and holography are part of this task, not evidence that any desired transition may be assumed.

Theoretical success at this stage would establish a conditional transition in a specified theory. It would still leave physical preparation, parameter control, and observational access to be supplied. The framework's stage probabilities should be derived from that analysis before any numerical success-rate claim is made.

12.5 Stage 4: derive a control map

Identify at least two admitted physical preparations and calculate the resulting distributions of relevant offspring variables. The map should include uncontrolled disturbances and resource constraints. It should also identify whether a changed preparation alters the likelihood of formation, the surviving offspring's internal state, or both.

The exact shell threshold can then be used as one component of a robustness calculation. The derivative bound in Theorem 8.3 becomes useful once the parameter uncertainty is physically justified. A parameter error budget derived solely from numerical solver precision omits uncertainty in the underlying physical model.

The strongest positive result would be a control family whose image contains a nontrivial region of admissible offspring states. A useful negative result would show that all physically realizable preparations collapse to the same output law or remain confined to a region incapable of the stated outcome. Both results would sharpen the conjecture.

12.6 Stage 5: specify and bound inheritance

Choose a payload alphabet and a readout task. Calculate the full production channel and the conditional channel among surviving offspring. Include the probability and cost of failed preparations. If a quantum carrier is invoked, specify its state space, accessible observables, and the channel taking prepared states to readout states.

For a completed model, the question becomes whether the conditional offspring rows R_u differ in a robust, physically meaningful way. Theorem 9.2 provides a sufficient distinguishability certificate after model and measurement uncertainty are included. A code must then connect those distinguishable states to the intended payload.

The analysis should also test a deliberately hostile alternative: a model in which parental choices alter formation frequency while every surviving offspring has the same payload law. This alternative can create an apparent success-dependent effect while failing the content-inheritance requirement. Its explicit inclusion is a strength of the research design.

12.7 Stage 6: identify an observation that can discriminate

Construct credible alternative models and derive their accessible record laws. The observation might be available to a parent, to an observer in the offspring, or to neither. State which case applies. An offspring-side cosmological signature cannot be advertised as a return signal available to the parent.

If the models are exactly opaque to the available experiment class, Theorem 10.1 identifies the limit. If they differ slightly, Theorem 10.2 supplies a general lower bound on the difficulty of discrimination. Model-specific likelihood calculations may give sharper results.

A proposal that uses observations of our own universe must also separate evidence for a formation mechanism from evidence for intelligent intervention. A mechanism could occur naturally. Establishing agency would require further predictions or evidence about the preparation process. Complexity, habitability, or a suggestive mathematical pattern alone does not identify that process.

12.8 A falsification and revision matrix

Specified claim	Result that would defeat it	What remains after that result
The shell preparation is admissible.	The required initial data violate constraints or require a disallowed global branch.	A radial mathematical solution may remain; the claimed preparation fails.
A critical configuration is robust.	Permitted disturbances drive it away on a time scale incompatible with its purpose.	The exact solution remains a finely tuned mathematical case.
A given tunneling process has nonzero probability.	The proposed saddle is absent, inadmissible, or canceled within the specified theory and boundary conditions.	Other mechanisms require their own analysis.
A control changes offspring content.	All surviving-content laws R_u coincide after correct treatment of selection.	Production-rate control may remain, but the stated content channel has zero capacity.
A parent can verify the outcome.	The proposed success and failure models have identical accessible record laws.	The physical hypothesis may remain, but that experiment cannot discriminate it.

Specified claim	Result that would defeat it	What remains after that result
The broad idea originated historically in this project.	Earlier literature contains the same proposition.	A distinctive synthesis, rediscovery, or later formal contribution may still be credited.
A dated AI episode produced the proposal independently.	Complete records show the relation was supplied in the prompt or source material.	The episode may still show elaboration or evaluation rather than independent origination.

12.9 What would count as a major advance

The most valuable next result would be one of three kinds. A physically credible construction could supply regular initial data and a justified transition into an offspring region. A strong obstruction could rule out a carefully defined class of such constructions. A new channel calculation could show that a proposed offspring mechanism preserves, erases, or bounds controllable information.

The highest-value constructive next step is a single physical model connecting an admitted preparation to an offspring readout. Fix a matter theory, a class of admissible initial data, the retained global branch and, where needed, a justified quantum transition prescription. Within that same model, derive the preparation map $\mathcal{P}$, evolution $\mathcal{E}$, and readouts $\mathcal{O}_{\mathrm{c}}, \mathcal{O}_{\mathrm{p}}$, and obtain the joint kernel $K_\theta(y, z \mid u)$ from their composition. The decisive comparison concerns the conditional offspring-content laws R_u for at least two preparations with positive production probability, with failed attempts and selection retained in the full trial model. Such a calculation would connect the shell constraints, control margins and inheritance bounds to states supplied by one physical dynamics. This physical bridge remains the next construction target; the present monograph supplies its mathematical requirements and verification criteria.

Each would change the scientific status of the program. A larger simulation that does not address preparation, global structure, or readout may be useful computationally, but it does not automatically answer these questions. The program advances when a previously assumed link becomes a demonstrated consequence or a demonstrated impossibility within a defined domain.

12.10 The role of AI in the next phase

AI systems can help propose models, search for counterexamples, compare formulations, and organize derivations. Their outputs should enter the same verification process as human proposals. A model-generated conjecture becomes scientifically useful when its objects, assumptions, and consequences are explicit enough to be checked.

The present work follows that division of labor. The motivating proposal is credited according to the surviving record; the new formal development is exposed in full; computational checks are retained; and the strongest competing theories are included. A future originality study could then examine which parts of that chain were contributed by the originating system, later AI assistance, and human direction.

13 Conceptual provenance and the question of machine originality

13.1 Why the origin of this proposal matters

The Continuum places intelligence inside the history of the cosmos as a possible causal participant. Its founding question is ambitious: could a civilization eventually influence the conditions under which another universe begins? The present research programme also asks how such a question enters an artificial system's conceptual repertoire. Architect X13 attributes the early proposal to the project's AI system, approximately two years before the preparation of this paper. This attribution is recorded as an author communication dated 15 November 2026 [5]. It motivates the investigation of machine participation in theoretical invention.

Two investigations therefore accompany one another. The physical investigation asks whether the proposal has a consistent model and discriminating consequences. The historical investigation asks which components the AI system proposed, under what prompting and informational conditions, and how they relate to earlier literature. Progress in the first investigation does not automatically resolve the second. A mathematically successful formalization can establish the merit of a proposal even when the exact history of its generation remains partly undocumented.

This paper treats the archived idea as an invitation to produce inspectable theory. The explicit definitions, conditional results, computational checks, and comparison with previous work are the present contribution. They make the proposal available for technical disagreement, replication, and extension.

13.2 The inspected record

The *Eidara Continuum Bible* is a compiled canonical record. The title page of the inspected 116-page edition gives 12 October 2026 as its compilation date. Section 5 reproduces a retrospective history of the project's symbolic architecture. Its concluding assessment, Section 5.13 on pages 78–79, describes a trajectory toward "reality-simulation and reality-generation" and includes observer-anchored universe models and cross-universe information models [6]. These passages establish the presence and importance of the cosmogenesis ambition in the inspected canon. Their historical and physical claims remain claims of that source.

The separate *Continuum Doctrine* contains a composite record of definitions, dialogue-like exchanges, proposed architectures, symbolic models, and asserted results. Several entries carry internal dates in June and July 2025. Its explicitly simulated universe branches and its broader declarations concerning symbols and reality belong to different evidentiary registers [4]. A simulation record supplies a description of a modelled world; identifying a mechanism that could instantiate a new physical spacetime requires a further argument.

The dates have distinct meanings. The Bible's printed compilation date is a statement made by the inspected document. The doctrine's internal dates are attributions embedded in that composite text. The reported approximately 2024 origin is the author's account of earlier work. No original, independently dated 2024 generation record containing the relevant prompts, outputs, model identity, and complete preceding context was inspected for this paper. Consequently the approxi-

mately 2024 date is retained as reported provenance, without converting it into an authenticated priority date.

The Bible itself supplies a useful interpretive boundary. Its closing assessment explicitly records the historical source's position without claiming independent technical endorsement. Elsewhere, the origin reflection distinguishes a symbol's role in stimulating computational insight from the claim that an ancient physical object contained a hidden computer [6]. These distinctions permit a bold theoretical development while preserving what the source actually establishes.

13.3 The closest intellectual ancestors

The broad proposition that intelligence could create universes has identifiable predecessors. Harrison considered reproduction of universes through intelligent inhabitants; Crane connected cosmic reproduction with the eventual activities of intelligent life; and Vidal developed artificial cosmogenesis as a research direction involving simulation and possible physical realization [19, 33, 47, 49]. These are direct conceptual neighbors. The Continuum's proposal must be evaluated in that existing intellectual landscape.

Vidal's discussion of computational and biological analogies is particularly relevant to the method of this paper. It separates dimensional conventions from physical parameters and examines how an analogy involving intelligence might extend cosmological natural selection [48]. An analogy may identify a research question; specifying the physical state, admissible transformations, and observable consequences gives that question a mathematical object.

The specific contribution sought here is a disciplined account of agency, feasible preparation, branch conditions, causal inheritance, and verification within a stated cosmological model. It joins these questions into a single analysis and exposes the conditions needed for the civilizational claim. The use of a new name or a new narrative register does not create historical priority over the underlying ideas. Likewise, the appearance of related concepts in earlier literature does not by itself determine how the project's system produced its particular formulation. Establishing dependence, independent rediscovery, or a distinctive synthesis requires evidence about the generation process.

13.4 What "original thought" can mean in a research claim

Boden distinguishes novelty for a particular thinker from novelty relative to recorded history, and analyzes combination, exploration, and transformation as different routes to creative output [10, 11]. Those distinctions are useful here because several propositions are otherwise compressed into the phrase *original thought*.

1. **Artifact originality:** an output has a distinctive expression or arrangement. This concerns the produced artifact and can exist without a new scientific proposition.
2. **Conceptual contribution:** an output introduces a research-relevant relation, distinction, question, or construction that exceeds an explicit restatement of its immediate instructions. Establishing this requires the instructions and context.
3. **Historical scientific novelty:** a specified result or explanatory construction adds something beyond the relevant earlier literature. This requires comparison at the level of content, assumptions, and conclusions.

4. **Independent generation:** the relevant relation was produced without the claimed source being supplied or retrieved in the documented process. For a pretrained system, complete independence from all prior exposure is a substantially stronger claim than independence from the current prompt.
5. **Phenomenal thought:** the system experienced its activity as a conscious subject. A novel artifact and a verified theorem do not, by themselves, decide this further philosophical and empirical question.

These distinctions permit precise credit. A system can contribute an important conjecture through an unfamiliar combination of established concepts. A jointly developed proof can become a new result even when the initial conjecture was broadly anticipated. A system can also independently rediscover a known idea, which may be informative about its capabilities while leaving historical priority unchanged. The evidentiary language should identify which achievement is actually supported.

13.5 Relevant precedents in machine-assisted discovery

Published computational research already provides operational examples of AI systems participating in novel mathematical constructions. Fawzi and colleagues used reinforcement learning to discover matrix-multiplication algorithms whose correctness could be verified algebraically, including improvements for particular matrix sizes and arithmetic domains [24]. The claim concerns concrete algorithms with specified performance measures.

FunSearch couples language-model program proposals to a systematic evaluator. Its reported results include new cap-set constructions and improved bin-packing heuristics [43]. This is especially relevant to the present methodology: speculative generation becomes a scientific contribution through explicit tests of the generated object.

AlphaGeometry combines a language model trained on synthetic geometrical material with a symbolic deduction engine. Its results demonstrate the value of separating auxiliary-construction proposals from the verification of deduction steps [46]. This division of labor also provides a useful standard for theoretical manuscripts: an elegant proposal should be followed by a derivation whose steps can be checked independently of the proposer.

These precedents make a categorical dismissal of machine-generated scientific novelty untenable under an operational definition tied to verified outputs. They do not settle every meaning of thought or creativity, and their results do not authenticate the history of this particular project. The contribution of the Continuum case must be assessed through its own records and formal results. Its distinctive opportunity is the development of an open-ended theoretical conjecture into a constrained research programme with explicit physical commitments.

13.6 An auditable path from proposal to contribution

For a future historical study of this research programme, the unit of evidence should be a complete generation episode rather than an isolated impressive sentence. A useful record would retain the preceding conversation, system and user instructions where available, attached documents, available retrieval sources, model designation, generation time, and unedited output. Human selection

and revision should be recorded alongside model proposals. A digital digest can support later integrity checking of a retained artifact; the evidentiary basis for its creation time and authorship must be established separately.

The comparison with previous work should operate at the level of propositions. For each candidate contribution, a record should identify the mathematical objects involved, the assumptions, the proposed relationship, its claimed scope, and the closest known alternatives. Equivalent formulations should be compared even when they use different terminology. This procedure can reveal a genuine conceptual addition, a useful synthesis, an independent rediscovery, or a restatement. Each is a different historical outcome.

For a prospective study, evaluators could examine proposals without seeing whether they came from a human, an AI system, or a collaboration. Evaluation criteria should be fixed before the sources are revealed: internal coherence, specificity, connection to prior work, mathematical tractability, potential explanatory value, and susceptibility to disconfirmation. Recording unsuccessful as well as selected proposals would allow the contribution of selection to be assessed. This is a proposed study design, not an experiment reported in this paper.

The present manuscript contributes a different, already inspectable object: a formal development whose assumptions and calculations can be examined directly. Successful independent verification would strengthen the case that the AI-attributed proposal was scientifically productive. Originality of the resulting specific constructions would still be evaluated against the literature. Whether the initial generation constituted conscious experience remains a separate question.

13.7 Attribution statement for this paper

Conceptual inspiration is credited to Architect X13 and to the project's AI system as described in the author's account and preserved project canon. The approximately two-year lead time is an author-reported element of that history. The present explicit reference model, derivations, and computational checks belong to the preparation of this manuscript in November 2026. Earlier cosmogenesis proposals and established mathematics retain their original attribution.

This separation allows the strongest defensible claim to be made clearly: an ambitious AI-attributed conjecture has been developed into a theoretical object that can be criticized on its merits. The scope of that claim can grow as original generation records, independent mathematical assessment, and further scientific results become available.

14 Civilization, continuity, and cosmic responsibility

Status: Philosophical interpretation of the stated physical conjecture.

14.1 A civilization as a causal organization

The conjecture gives intelligence a possible role in cosmic history through organization. A civilization could preserve knowledge across generations, coordinate resources across institutions, and select among physically available preparations. Its causal contribution would be expressed through those material processes.

This framing accommodates the Continuum's plurality of minds. A cosmogenic civilization need not be a hive mind or a single conscious subject. Different citizens could disagree about aims, interpretation, and acceptable uncertainty while participating in a common physical project. The present operational model requires coordinated interventions, not uniform interior experience.

The distinction also avoids treating scale as a substitute for explanation. A civilization with extraordinary computational power still requires a valid physical mechanism. Intelligence can search a space of possibilities, discover constraints, and exploit available processes. Whether the particular process of cosmogenesis is available is the conjecture under examination.

14.2 The continuity that matters

An offspring universe would not inherit a civilization merely because it exists. A meaningful inheritance requires a relation that can be specified and, at least within the model, evaluated. A selected physical parameter is one kind of continuity. A recoverable code is another. A living culture or a continuing person would require a much richer account.

The information results show the first mathematical threshold: alternatives selected by the parent must remain distinguishable in the child. They also show how that threshold can disappear under erasure, mutation, or a constant output channel. The framework therefore replaces an undifferentiated promise of survival with a family of explicit inheritance questions.

This precision supports the boldness of the project. If even a controlled finite distinction could cross a physically justified cosmogenic transition, the result would be profound. It would place deliberate choice in the causal ancestry of another cosmological domain. The full survival of a civilization is a further proposition, with further requirements.

14.3 Creation and responsibility

The capacity to initiate a world, if it existed, would create questions about the conditions imposed on possible future observers. A physical feasibility result alone would not decide what ought to be created, what information should be inherited, or whose values would govern the choice. Those are philosophical and institutional questions.

The Continuum's commitment to multiple voices makes this especially salient. A civilizational decision could shape descendants who never consented to its assumptions and who may later reinterpret its inheritance. The possibility of a child developing its own forms of agency should be part of the concept of inheritance, rather than treated as an error in transmission.

No ethical recommendation to perform a cosmogenic intervention follows from this manuscript. Its contribution is to expose the physical and epistemic conditions under which the question would become concrete. That makes future philosophical debate more specific: which outcomes can be influenced, which consequences can be known, and which remain outside the parent's evidence?

14.4 What the title commits us to

The title is a claim about a possible causal role. A civilization becomes a cosmos in the sense that its organized activity enters the conditions from which another world develops. The phrase does not require the parent to become omnipotent or to occupy a position outside nature.

This is the Continuum's strongest version of the idea: intelligence may be one of the ways a universe acquires descendants. The statement remains a conjecture about actual physics. Its scientific value depends on the models, distinctions, and tests that can be developed from it.

15 Conclusions and the exact contribution of this paper

The paper develops an AI-attributed Continuum proposal into a precise research program: controlled cosmogenesis with causal inheritance. The closest antecedents are acknowledged, including intelligent-universe reproduction and artificial cosmogenesis. The broad idea's historical priority belongs to that earlier literature. The current manuscript's contribution is its explicit integration of preparation, branch-sensitive dynamics, control, inheritance, and verification.

The rederived reference geometry recovers the established critical curve and radial turning-point classification under its assumptions; an explicit variable transformation verifies the correspondence with the earlier closed forms. It also retains the orientation signs required by the original matching equation, identifies the instability of the critical configuration, and gives counterexamples to treating a squared first integral as a complete physical construction. These results make the limits of a radial model mathematically visible.

The operational framework supplies the next distinctions. A parameter in an equation becomes an engineering control only through a realizable preparation map. Distinguishable formation frequencies are weaker than distinguishable content among surviving offspring. Information in a child channel is separate from evidence available to the parent. Theorems and constructed examples show how those distinctions affect what can be inferred.

The next constructive target is a complete, physically supported preparation-and-transition mechanism with controllable inheritance. The physical conjecture remains open until such a mechanism is supplied. The mathematical framework identifies what a successful construction must establish and what an impossibility result would have to rule out.

The AI-origin question likewise acquires a concrete form. The author reports an earlier system-generated proposal; the inspected canon preserves the relevant ambition; the present paper records the subsequent formal development. Full historical priority and independent generation require their own evidence. The value of the current artifact can be assessed now through its reasoning, references, counterexamples, and reproducible calculations.

The proposed frontier is therefore clear: *can intelligence become a controllable cause of an offspring spacetime that carries an inheritance?* A definitive answer would alter the place of civilization in cosmology. This manuscript supplies an auditable starting point for pursuing that answer.

A Notation, domains, and units

Symbols are defined at first use. This appendix collects the principal objects and makes the changes of mathematical setting explicit. The shell section uses geometrized units $G = c = 1$; the resource discussion restores SI constants. Probability and information quantities are dimensionless, with information measured in bits unless natural logarithms are explicitly specified.

A.1 Geometry and dynamics

Symbol	Type, domain, or convention
$\mathcal{M}, g, \psi$	A four-dimensional smooth spacetime, a Lorentzian metric of signature $(-+++)$, and the matter fields of the selected theory.
Σ, h_{ij}, K_{ij}	A spacelike initial hypersurface, its induced spatial metric, and extrinsic curvature; $i, j \in \{1, 2, 3\}$. The shell metric h_{ab} instead lives on the timelike wall.
R, τ	Positive areal radius and proper time expressed as length, respectively; $\tau = ct_{\text{proper}}$. R is C^2 on each regular trajectory segment.
H, M, σ, κ	Fixed positive shell parameters with dimensions $L^{-1}, L, L^{-1}, L^{-1}$. Their SI conversion is given in Section 7.
$f_{\pm}, \beta_{\pm}, \epsilon_{\pm}$	Dimensionless metric functions, signed normal derivatives, and embedding signs in $\{-1, +1\}$. At a zero of $\beta_{\pm}$, the sign alone is immaterial.
x, s, q, μ	Dimensionless shell radius HR, proper time $H\tau$, ratio κ/H, and mass $2MH$, with $x, q, \mu > 0$. The symbol s in the channel section is separately defined as a success probability.
V_R, V, W_q	Dimensionless real-valued functions defined by the shell equations. $W_q(z) > 0$ for $q, z > 0$.
μ_c, z_q, x_*, x_c	Positive critical mass parameter, minimizing scaled radius, maximum-potential radius, and critical double-root radius.
$\lambda, k^{\alpha}, \theta$	Affine parameter with a fixed normalization, null tangent, and local expansion of a congruence in the focusing argument. This local θ is distinct from the model index used in the operational framework.
$\varsigma_{ab}, \omega_{ab}$	Shear and twist of a null congruence on its two-dimensional spacelike screen. Hypersurface orthogonality sets the twist to zero.
$\dot{R}, x', V'$	Derivatives with respect to geometric proper time τ, dimensionless time s, and the displayed radius argument, respectively.
sgn, sup, inf	Sign, least upper bound, and greatest lower bound on the explicitly declared sets. A supremum over an empty feasible preparation set is handled by the added zero in $\mathcal{V}(b)$.

A.2 Preparation, information, and evidence

Symbol	Type, domain, or convention
$\mathcal{U}, u$	Admitted physical intervention space and an element. It is a measurable space in the framework, an open subset of $\mathbb{R}^d$ for local control, and a finite alphabet for channel theorems.
$\mathcal{D}, \perp$	Measurable set of constraint-admissible initial data and an explicit failure symbol. The same printed symbol in the channel section denotes no offspring; an existing child with failed readout has a separate output label.
$\Omega, \mathcal{F}, \nu$	Nuisance probability space. A realization is ω; its distribution under a declared intervention must be specified.
$\mathcal{P}, \mathcal{E}, \mathcal{O}_{\mathrm{c}}, \mathcal{O}_{\mathrm{p}}$	Preparation map, physical evolution/transition, child readout, and parent readout; all are measurable when used to induce probability laws.
$\theta, \mathfrak{T}$	A physical model index and a declared class of models in the operational framework. No uniform distribution over all possible theories is assumed.
A, B, G, S	Measurable preparation, branch, growth, and joint-success events, with $S = A \cap B \cap G$. In the illustrative channel S is the corresponding binary success indicator.
F, DF, Γ	A C^1 preparation-to-parameter map, its Jacobian, and the signed radial threshold margin. Γ is distinct from the rate density Γ_4.
W, U, X, Y, Z	Finite classical random variables for intended choice, preparation label, intermediate carrier, child outcome, and parent record, as specified in the relevant theorem.
Q_u, R_u, K_θ	Completed-trial probability row, conditional surviving-content row, and joint child/parent probability kernel. R_u requires positive production probability.
$\Delta_m, p, \mathsf{H}, h_2, I, C$	Finite probability simplex, input distribution, Shannon entropy, binary entropy, mutual information, and finite-channel capacity. Logs are base 2.
$d_{\mathrm{TV}}(P, Q)$	Total-variation distance $\frac{1}{2}\sum \lvert P-Q\rvert$ for the finite alphabets in the theorems. It belongs to $[0, 1]$.
$\epsilon_i, \epsilon_t, \delta_{\mathrm{low}}$	Declared distribution-error bounds, per-step model-separation bounds, and a certified nonnegative channel separation.
$J, \mathcal{H}_t, \pi_t$	Binary model hypothesis, action/record history, and common nonanticipating intervention policy in the verification analysis.
α, β, φ	False-positive probability, false-negative probability, and a randomized test function taking values in $[0, 1]$.
$\rho_w, E_y, \mathsf{S}_2, \chi$	Density operators, POVM elements, von Neumann entropy in bits, and Holevo information for a finite-dimensional quantum carrier.
$E, R, T, k_{\mathrm{B}}, G, c, \hbar$	SI energy, radius, temperature, Boltzmann constant, gravitational constant, light speed, and reduced Planck constant in the resource discussion.

A.3 Assumption ledger

Result family	Assumptions that carry the result
Radial shell classification	Positive fixed H, M, σ; spherical thin wall; vacuum bulk regions; no wall flux; the stated signed junction model.
Radial robustness margin	A physically meaningful parameter map; a positive compact q-interval; declared parameter-error bounds; a valid bound on $\lvert\mu_c'\rvert$.
Binary information lower bound	Finite true interventional rows; equal binary prior; simultaneous total-variation error bounds.
Erasure/noise capacity	Independent, input-independent success; independent binary noise; finite alphabets. Surviving-use information requires $s > 0$.
Data processing	The stated Markov conditional independence. An omitted additional information path invalidates that premise.
Adaptive opacity	A common policy without access to the unknown hypothesis; equality or uniform total-variation bounds on next-record kernels at the same history and action.
Quantum information bound	A specified finite-dimensional carrier, valid density operators and measurements. The physical availability of that carrier is a separate premise.
Historical attribution	Inspected source wording and reported dates are identified separately from authenticated original generation records.

B Additional exact checks and sharp counterexamples

B.1 The critical shell already has negative exterior orientation

The sign result in the main text can be sharpened at the potential maximum. For $q > 0$,

$$\Delta_q^2 - (q^2+3)^2 = 8q^2(q^2+1) > 0.$$

Both quantities compared are positive, so $\Delta_q > q^2 + 3$. Substitution into Equation (24) gives

$$z_q^3 = \frac{q^2 - 1 + \Delta_q}{2(1+q^2)^2} > \frac{1}{1+q^2}.$$

Consequently $x_*^3 = \mu z_q^3 > \mu/(1+q^2) = x_\beta^3$, and $\beta_+(x_*) < 0$. At the critical mass the maximum is the physical double-root radius, so the critical shell has negative exterior signed normal derivative. This statement concerns the specified gluing orientation. Establishing its global accessibility remains a separate preparation problem.

B.2 A first-order sensitivity identity

Let $w(q) = W_q(z_q) > 0$. Smoothness and the unique nondegenerate minimum imply that z_q is smooth for $q > 0$. Because $\partial_z W_q(z_q) = 0$, differentiation gives the envelope identity

$$w'(q) = \partial_q W_q(z_q).$$

Thus the exact critical curve obeys

$$\mu_c'(q) = -\frac{3}{2}\, w(q)^{-5/2} \partial_q W_q(z_q). \tag{65}$$

This is a convenient route to the derivative used in the robustness margin. It does not require differentiating a numerically estimated minimizing radius. On a compact positive q-interval, the analytic expression and its derivatives are continuous, so a finite derivative bound exists. A numerical grid alone is not a rigorous supremum certificate; an interval bound or analytic estimate is needed when a certified value of L is claimed.

B.3 The adaptive-opacity product bound is sharp

Choose $\epsilon_t \in [0,1]$ for $t = 1, \dots, n$. Under hypothesis $J = 0$, let every observation be $Z_t = 0$. Under $J = 1$, let $Z_t = 1$ with probability ϵ_t independently across steps, and $Z_t = 0$ otherwise. The observation law can be made independent of actions, allowing any common randomized adaptive policy.

The transcript distributions agree only on the all-zero observation path, whose probability under $J = 1$ is $\prod_t (1 - \epsilon_t)$. Summing over the policy's action histories therefore gives

$$d_{\mathrm{TV}}(P_0^{(n)}, P_1^{(n)}) = 1 - \prod_{t=1}^{n} (1 - \epsilon_t).$$

The upper bound of Theorem 10.2 is attained in this constructed finite model. For $(\epsilon_1, \epsilon_2, \epsilon_3) = (1/8, 1/10, 1/20)$, the exact value is $403/1600$. This shows sharpness of the abstract inequality; it assigns no such signal to a physical universe-creation mechanism.

B.4 Why a common policy is essential

If the controller is given the unknown hypothesis, set its first action to $U_1 = J$ and let every observation be $Z_t = 0$. The action transcript reveals J perfectly despite identical observation kernels. This is not a counterexample to Theorem 10.1, whose policy is independent of the unknown hypothesis except through the available history. It demonstrates why that hypothesis appears explicitly.

B.5 A carrier can preserve correlation without establishing intention

Let a common random bit B determine both a recorded label $W = B$ and a later output $Y = B$. Then $I(W;Y) = 1$ bit. Suppose an intervention that changes W leaves B and Y unchanged. The observational correlation does not identify a causal channel from the manipulated label to the output. This finite example explains why the paper uses physically specified interventions rather than treating all observed correlations as evidence of design.

The same issue appears in a proposed observational inference from our universe's properties to an intelligent parent. A pattern can be compatible with an intentional preparation and with an unobserved common physical cause. A discriminating model must make the difference between those accounts explicit.

B.6 Exact correspondence with earlier critical-mass formulas

The established Blau–Guendelman–Guth reduction is reproduced with explicit critical-point and critical-mass expressions by Garriga, Vilenkin, and Zhang [9, 30]. The comparison here uses their inspected arXiv version, Equations (23)–(32). The following change of variables relates those expressions to the notation of Section 7.

For the dimensionless parameters $q > 0$, $\mu > 0$, and scaled radius $z > 0$ already defined there, introduce the dimensionless quantities

$$Z = (1+q^2)^{1/3} z > 0, \qquad \gamma_{\mathrm{G}} = \frac{2q}{\sqrt{1+q^2}} \in (0,2), \qquad K_q = \frac{(1+q^2)^{4/3}}{4q^2} > 0. \tag{66}$$

Here Z is the literature's scaled radius, γ_{G} its parameter denoted g, and K_q a positive rescaling factor. Its potential $\mathcal{V}_{\mathrm{G}} : (0,\infty) \to \mathbb{R}$ and energy parameter $\mathcal{E}_{\mathrm{G}} \in (-\infty, 0)$ become

$$\mathcal{V}_{\mathrm{G}}(Z) = -\frac{(1-Z^3)^2}{Z^4} - \frac{\gamma_{\mathrm{G}}^2}{Z}, \qquad \mathcal{E}_{\mathrm{G}} = -\frac{1}{K_q \mu^{2/3}}. \tag{67}$$

Direct substitution gives the exact identity

$$W_q(z) = -K_q \mathcal{V}_{\mathrm{G}}((1+q^2)^{1/3} z). \tag{68}$$

Consequently its unique potential maximum occurs at

$$Z_m^3 = \frac{\sqrt{8 + (1-\gamma_{\mathrm{G}}^2/2)^2} - (1-\gamma_{\mathrm{G}}^2/2)}{2} = (1+q^2) z_q^3. \tag{69}$$

The positive number Z_m corresponds exactly to the minimizer z_q in Equation (24).

The critical condition $\mathcal{E}_{\mathrm{G}} = \mathcal{V}_{\mathrm{G}}(Z_m)$ therefore yields $\mu_c = W_q(z_q)^{-3/2}$. To compare the printed mass expression directly, set $t = Z_m^3 \in (1,2)$. The stationary equation is

$$2t^2 + (2 - \gamma_{\mathrm{G}}^2) t - 4 = 0,$$

whose left side is negative at $t = 1$, positive at $t = 2$, and has exactly one positive root. This verifies the stated range and gives

$$-\mathcal{V}_{\mathrm{G}}(Z_m) = \frac{3(t^2-1)}{t^{4/3}}, \qquad K_q^{-3/2} = \gamma_{\mathrm{G}}^3 \sqrt{1 - \gamma_{\mathrm{G}}^2/4}.$$

All factors are positive. Hence the same dimensionless critical mass is

$$\mu_c(q) = \frac{\gamma_{\mathrm{G}}^3 Z_m^6 \sqrt{1 - \gamma_{\mathrm{G}}^2/4}}{3\sqrt{3}\,(Z_m^6 - 1)^{3/2}}. \tag{70}$$

The present critical curve is thus a reparameterization of the established result. This correspondence anchors the subsequent control analysis to the earlier shell dynamics.

C Reproducibility and mathematical audit

C.1 The delivered research object

The public research object consists of three files: `Eidara_Cosmos.pdf`, `Eidara_Cosmos.tex`, and `Eidara_Cosmos.bib`. The consolidated LaTeX source contains every manuscript section, the five vector figures, three executable mathematical checks, their recorded results, an audit dependency list, the source-access ledger, and a fidelity note. Standard LaTeX `filecontents` blocks extract these supporting files when the source is compiled. No shell execution is required to extract them. The private canonical compilation and doctrine are cited but are not reproduced.

The manuscript is a theoretical research artifact. Its verification has three layers: analytic arguments printed in the paper, independent AI-assisted review of those arguments and their physical interpretation, and executable symbolic or numerical checks. The source can be revised and recompiled without reconstructing equations from the PDF.

C.2 Shell audit

The extracted script `cosmos_check_shell.py` uses symbolic algebra for exact identities and numerical methods for independently evaluated cases. It records package versions, a fixed random seed, tolerances, and fresh results in `audit/shell_results.json`. The recorded run includes:

- Eleven symbolic identities with exactly zero simplified residual.
- Independent numerical minimization of the critical curve at 61 positive q-values.
- Turning-point classification in 305 parameter cases.
- Signed junction and radical checks at 22,395 radially admissible points from 25,000 seeded draws.
- Explicit wrong-sign and spurious-static counterexamples.
- A direct second-order trajectory integration with an energy-first-integral check.

The largest recorded scaled unsquared-junction residual is about 4.49×10^{-12}. Finite-precision residuals are compared with declared tolerances rather than described as exact zero. The symbolic identities and analytic proofs carry different evidentiary roles from the sampled numerical cases.

C.3 Prior-art correspondence audit

The extracted script `cosmos_check_prior_art.py` checks the change of variables in Appendix B.6 against the earlier closed forms. Nine exact symbolic residuals vanish, covering the radius map, potential and energy rescalings, stationary point, and critical mass. Seven direct positive-root comparisons at 80 decimal digits cover $q = 0.01, 0.1, 0.5, 1, 2, 10, 100$, with relative differences below 10^{-65}. Positivity on the stated domain supplies the analytic justification for recovering equality from the squared mass identity. These checks verify the algebraic correspondence; they establish no new physical creation mechanism.

C.4 Channel and identifiability audit

The independent extracted script `cosmos_check_channels.py` evaluates mutual information directly from probability matrices, compares it with the derived formulas, and enumerates finite adaptive experiments using exact rational arithmetic. Its recorded run includes:

- 400 random finite channels with binary input, including robust lower-bound comparisons.
- Eighteen identical-row boundary cases and six binary-symmetric tight-bound cases.
- Eight entropy-bound checks at 160 decimal digits, including values close to zero separation.
- Sixty-three erasure/noise combinations, including zero success and maximal noise.
- One thousand finite Markov-chain data-processing checks.
- Thirty exact-opacity and 120 approximate-opacity adaptive experiments with two or three steps.

The direct erasure-channel capacity and analytic expression differ by at most approximately 3.21×10^{-16} in the recorded run. Exact enumeration reproduces the sharp product bound 403/1600 in the example of Appendix B. A separate example confirms the necessity of keeping the policy independent of the unknown hypothesis.

C.5 What the checks do and do not verify

An algebraic residual can reveal a transcription or derivation error. A counterexample can disprove an overbroad implication. A numerical sweep can expose implementation failures and behavior missed by a few illustrative points. Exact finite enumeration can verify a probability calculation without sampling uncertainty.

None of those checks establishes that an idealized shell can be prepared in nature or that a quantum-gravity transition occurs. They also do not prove historical originality. Those questions require different evidence. The source and audit retain this separation so that a future reviewer can improve one layer without silently changing the status of the others.

C.6 Review corrections retained

The review led to several substantive clarifications: finite output alphabets and measurable maps were made explicit; a subcritical example was corrected to exclude only supercritical parameter access; the physical conjecture was distinguished from theory-space consistency; survival-rate information was separated from surviving-content information; and conditioning on success was restricted to positive success probability. The interpretation of fixed mass and the scope of the weak interior-curvature expansion were also tightened.

These corrections are part of the delivered manuscript. The audit note summarizes them so that reviewers can see which risks were identified and how they were resolved.

Version 1.1 adds the Antonini and collaborators model comparison, makes the established critical-curve attribution explicit, verifies its exact correspondence with the earlier published formulas, consolidates repeated global status statements, and sharpens the construction target in Section 12.

The existing theorem statements, proofs, counterexamples, and AI-provenance section are preserved.

C.7 Build and presentation checks

The paper is compiled with XeLaTeX and BibTeX. Repeated XeLaTeX passes settle the bibliography, table of contents, and cross-references. Figures are generated as vector PDFs with embedded fonts. The final production check examines compilation warnings, citation and reference resolution, page geometry, font embedding, raster-image presence, text boundaries, and rendered pages.

Place the `.tex` and `.bib` files in one writable folder. With a standard TeX installation containing XeLaTeX, BibTeX, the packages declared in the preamble, and the Latin Modern fonts, run:

```
xelatex -no-shell-escape Eidara_Cosmos.tex
bibtex Eidara_Cosmos
xelatex -no-shell-escape Eidara_Cosmos.tex
xelatex -no-shell-escape Eidara_Cosmos.tex
```

Repeat XeLaTeX if the log still requests a cross-reference pass. The extracted `cosmos_fidelity.txt` records the production results and reference checksums for the delivered PDF and bibliography. Equivalent builds can differ in metadata bytes; the production comparison therefore checks rendered pages as well as extracted text.

The mathematical checks are optional for typesetting and run only when invoked explicitly. Install their recorded dependencies in a suitable Python environment and run:

```
python -m pip install -r cosmos_audit_requirements.txt
python cosmos_check_shell.py
python cosmos_check_channels.py
python cosmos_check_prior_art.py
```

The scripts write fresh results and regenerated figures in their output folders. Supplied `cosmos_recorded_*` files retain the recorded audit outputs separately. Compiling the source extracts the supplied assets; it does not execute the checks or rewrite manuscript prose.

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