From Necessary Facts to Physical Structure: Why Fact-Based Physics Highly Constrains the VERSF Architecture

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Once a physical theory is required to produce stable, distinguishable, localized facts, its structure is highly constrained. The VERSF framework is the organized realization of those constraints.

For the General Reader

Physics is the science of what actually happens. But for anything to "actually happen," there must be a record of it — a stable, identifiable outcome that persists long enough to be known. We call such outcomes *facts*. This paper asks a deceptively simple question: what must the universe be like in order for facts to exist at all?

The answer, it turns out, is highly specific. Once you take seriously the requirement that the universe produce real, stable, distinguishable outcomes, the structure of physical law becomes tightly constrained. This paper traces that constraint chain from first principles.

The argument proceeds in stages. First, we show that any region of space capable of producing a fact must meet a quantitative energy threshold — small regions with little energy simply cannot lock in an irreversible outcome. This threshold separates two regimes: a pre-factual world of possibilities and reversible processes, and a factual world of irreversible commitments and stable records. Quantum mechanics turns out to be the unique physics of the pre-factual regime; classical, irreversible record formation is what happens when the threshold is crossed.

Second, we show that the smallest possible fact-bearing unit has a precise internal structure — seven independent constraints, no more, no fewer — determined by the mathematics of error-correcting codes applied to the requirements of stability and distinguishability.

Third, we show that the accumulation of facts generates time, and that the distribution of facts across space generates gravity and geometry. Newton's constant — the strength of gravity — can be expressed in terms of the rate at which facts form and the scale at which they form.

Finally, we prove that any physical theory satisfying these requirements is structurally equivalent to the VERSF (Void Energy–Regulated Space Framework). VERSF is not one model among many. It is the unique organized expression of what a fact-producing universe must look like.

The paper is technical in its methods but rests on a single, accessible idea: if physics must describe things that actually happen, then physics must have a very specific structure — and that structure is derivable.

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Abstract

Physics is not merely a theory of possibilities — it is a theory of what is the case. Any physically meaningful universe must therefore admit the formation of facts: localized, distinguishable, and persistent outcomes. The necessity of fact-production is established by the Joint Necessity Theorem [34]: any universe possessing physical time and physical law must be fact-producing, from which finite distinguishability and irreversible commitment follow as structural necessities.

We show that the formation of an irreversible fact requires that a bounded region satisfy the Causal–Coherence Compatibility (CCC) condition

$$\rho L^4 \gtrsim \hbar c$$

which follows directly from finite distinguishability and causal irreversibility, with no additional postulates. This condition defines a coherence scale ξ separating proto-factual ($\chi < 1$) and factual ($\chi \geq 1$) regimes. Finite local capacity is not an independent assumption — it is a consequence of this threshold: a region satisfying CCC necessarily supports at least one unit of commitment capacity, and the threshold itself defines the capacity bound.

We further show that stability constraints on fact-bearing structures force a minimal internal architecture of $K = 7$ independent constraints — derived via a no-go theorem for relational substrates and the Hamming (7,4) encoding of commitment states. The accumulation of irreversible commitments generates physical time. Their spatial distribution defines an entropy field sourcing spacetime geometry, with Newton's constant reducible to commitment rate and coherence scale.

VERSF is not an independently postulated framework. It is the organized realization of the minimal structure any universe must possess if physical facts are to exist.

Structural Summary: Reconstruction of Physics from Facthood

If a physical theory is required to produce stable, distinguishable, localized facts, then its structure is highly constrained. Starting from two primitive requirements — **finite distinguishability** and **irreversible commitment** — the following structural chain is derived:

Facthood ⟹ CCC threshold ⟹ proto/factual regime split ⟹ PAR (reversible sub-threshold dynamics) ⟹ unitary evolution (QM structure; contingent on Paper B2) ⟹ finite local capacity ⟹ minimal fact architecture ($K = 7$) ⟹ record-sourced geometry ⟹ Einstein-type field equations

Each step is either derived from prior constraints or independently fixed by a rigidity theorem.

Within the admissibility class **F** of fact-producing theories, this paper establishes:

Rigidity result	Claim
Threshold-class rigidity	No alternative commitment threshold exists within **F**
Reversible-sector rigidity	Sub-threshold dynamics are uniquely unitary (contingent on Paper B2)
Minimal architecture rigidity	No alternative minimal fact structure exists within **F**
Source-to-geometry rigidity	Geometry is uniquely sourced by committed records
Geometry-equation rigidity	Admissible field equations are uniquely Einstein-type (given 3+1 dimensions)

These results jointly imply, contingent on the formal category-theoretic definition of **F** (Paper A):

Any admissible fact-producing theory is structurally equivalent to the VERSF framework, up to structural equivalence.

The remaining freedom — monotone reparameterization of the threshold, field redefinition in the record sector, normalization, cosmological constant convention, and coordinate gauge — is representational rather than physical. It does not define distinct theories; it defines different descriptions of the same theory.

VERSF is therefore not an arbitrary model, but the unique structural equivalence class of admissible fact-based physical theories within **F**.

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1. Introduction

Physics seeks to describe reality. But reality is not exhausted by a catalogue of possibilities. It includes actual outcomes: events that occur, states that are realized, records that persist. If a theory admits only possibilities without ever producing facts, it cannot describe a physical universe. There would be no measurement outcomes, no stable configurations, no persistent structures, and no distinguishable history. A theory of physics must therefore admit the production of facts.

The central question of this paper is:

What structural conditions must a universe satisfy in order for physical facts to exist?

We show that this question imposes sharp constraints on admissible physical architectures. These constraints are not derived from any particular model — they precede model choice. Once they are made explicit, they narrow the space of viable frameworks considerably, and they generate — step by step — the core architecture of the VERSF framework.

It is worth acknowledging at the outset what this argument does and does not establish. It does not claim that VERSF is the *only* framework consistent with fact-based physics. Other discrete or relational frameworks — including causal set theory, loop quantum gravity, and relational quantum mechanics — share some of these structural commitments, and a serious comparison with those traditions is part of the broader research programme. What the argument *does* establish is that VERSF satisfies each constraint non-trivially, that its architecture is not arbitrary, and that competing frameworks face structurally analogous demands that they must answer on their own terms.

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2. Facts as a Necessary Condition for Physics

We define a **fact** as a physically realized outcome satisfying three minimal conditions:

- **Distinguishability** — it is identifiable relative to alternatives
- **Persistence** — it remains stable long enough to be meaningful
- **Localizability** — it is instantiated within a physical region

Without such entities, physics loses empirical content. Observations, measurements, and histories all depend on the existence of facts. More precisely: any theory that does not produce stable, distinguishable, persistent records cannot generate empirical predictions and therefore cannot function as a physical theory. This is not a metaphysical addition to physics — it is the operational minimum for physics to describe anything at all.

Core premise:

Any theory that generates empirical predictions must admit the formation of localized, persistent, distinguishable facts.

This premise is accepted — either implicitly or explicitly — by every major physical framework, whether continuous or discrete, relational or substantival. What differs is how each framework instantiates the structural machinery required to support it. The task of this paper is to make that machinery explicit and to show what it demands.

The necessity of this premise is not merely asserted. The Joint Necessity Theorem [34] establishes that any universe possessing physical time and physical law must be fact-producing: if time is real and law is operative, then outcomes must be distinguishable, fixed, and localized. The three corollaries of Section 3 therefore do not follow from a definition we have chosen — they follow from what it means for a physical universe to exist at all.

The definition of a fact used here is deliberately minimal and does not presuppose any particular physical framework. In particular, it does not assume discreteness, continuity, specific dynamics, or geometric structure. The three conditions — distinguishability, persistence, and localizability — are requirements on any physically meaningful outcome, not features of any specific model. The structural corollaries derived in Section 3 are therefore constraints on admissible physical theories, not restatements of a chosen framework. This distinction is critical: the argument proceeds from requirements that precede model choice, not from within any particular model looking outward.

Operational grounding of facthood. The necessity of facts is not merely conceptual — it is operationally enforced by empirical constraints on physical systems. All experimentally successful physics behaves as if: only finitely many perfectly distinguishable states are accessible in bounded systems; time is defined only through physical clock processes; and only finite information can be extracted from finite resources. These constraints imply that any physically meaningful outcome must be a finite, local, distinguishable record — precisely the definition of a fact used here. The requirement that physics admit facts is therefore not an additional assumption but a restatement of how all successful physical theories already operate under finite experimental access. A framework that rejects facthood must explain how its predictions are operationally accessible at all.

Theorem (Facthood Necessity — Operational Form). *Any theory that generates empirically testable predictions must admit the formation of stable, distinguishable, persistent records. Therefore, facthood is a necessary condition for physical theories.*

Proof. An empirically testable prediction is one that can be compared to a recorded outcome. Such comparison requires that the outcome be (i) stable — it must persist long enough to be compared; (ii) distinguishable — it must be identifiable as one outcome rather than another; (iii) localizable — it must be instantiated somewhere so that the comparison can be made. A theory that does not produce outcomes satisfying all three conditions cannot be compared to any observation, and therefore cannot generate empirical predictions. Any theory that generates empirical predictions must therefore admit the formation of stable, distinguishable, persistent records. These records are what we define as facts. ■

This theorem makes the operational status of facthood explicit: it is not a philosophical preference added to physics from outside, but a precondition already implicit in what it means for a theory to be physical.

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3. Structural Corollaries of Facthood

If facts are possible, then the underlying physical structure must support them. Three structural corollaries follow.

3.1 Finite Distinguishability

A fact must be distinguishable from alternatives. This implies a lower bound on physically meaningful differences. Without such a bound, distinctions dissolve into arbitrarily fine variations that cannot be realized or recorded — the fact cannot be *identified* as one outcome rather than another.

Corollary 1: *Physical systems must admit finite, non-zero distinguishability.*

This is realized differently across frameworks: as a minimal Planck-scale separation in loop quantum gravity, as a discrete causal link in causal set theory, and as a minimum admissibility threshold in VERSF. All share the underlying necessity. The VERSF realization has the specific feature of tying distinguishability directly to commitment dynamics, which generates additional structure explored below.

3.2 Irreversible Commitment

A fact is not a transient fluctuation. It represents a transition from possibility to actuality — a transition that must be irreversible in the sense that the outcome enters the physical record. Without irreversibility, all transitions remain equally revisable and no outcome is fixed; there are no facts, only amplitudes.

Corollary 2: *Physics must include a mechanism by which reversible possibilities give rise to irreversible, record-bearing commitments.*

Note that the *mechanism* by which irreversibility arises is a genuine open question across frameworks, not a solved one. Decoherence provides an approximate account within standard quantum mechanics. VERSF proposes a more fundamental commitment transition — a fold event — as a primitive. This is a substantive theoretical claim, not a mere relabelling, and it carries specific empirical consequences that distinguish it from the decoherence picture.

3.3 Finite Local Capacity

Facts must be instantiated somewhere. Any finite region must have a bounded ability to support and stabilize records. If capacity were infinite, localization would be undetermined; if zero, no facts could form.

Corollary 3: *Physical systems must have finite local capacity for fact formation and stabilization.*

This corollary has a special status among the three. While it follows from the nature of facthood, it is also a *consequence* of CCC: a region satisfying the threshold $\rho L^4 \gtrsim \hbar c$ necessarily supports at least one unit of commitment capacity, and the threshold condition itself defines the capacity bound from below. Finite local capacity is therefore not fully independent of Corollaries 1 and 2 — it is entailed by their conjunction once the CCC threshold is operative. This reduces the effective axiom count: the three corollaries present as three requirements, but the third is structurally generated by the first two via the physical threshold. The philosophical significance is that fact-bearing physics requires only two primitive structural commitments — distinguishability and irreversibility — with capacity emerging as their physical consequence.

3.4 Summary

These three corollaries are not optional. They are jointly the minimal structural requirements for fact-bearing physics:

Condition	Physical Role
Finite distinguishability	Makes facts identifiable
Irreversible commitment	Makes facts actual rather than possible
Finite local capacity	Makes facts localizable and bounded

Joint Facthood Constraint Theorem *(informal)*: Any physically meaningful framework that admits facts must satisfy, simultaneously, all three of the above conditions. No pair of conditions is sufficient; all three are jointly required.

This can be seen by considering the failure modes of each incomplete combination:

- *Distinguishability + capacity without irreversibility*: distinctions exist and are bounded, but all transitions remain revisable. No outcome is fixed; there are no facts, only persistent possibilities.
- *Distinguishability + irreversibility without capacity*: transitions are fixed and identifiable, but without finite local capacity there is no localization. Records cannot be placed; facts float free of any physical support.
- *Irreversibility + capacity without distinguishability*: transitions are fixed and bounded, but outcomes cannot be told apart. Commitment occurs, but to nothing identifiable; records are indistinguishable and therefore carry no information.

The three conditions are therefore not merely a list — they form a **minimal closed set**. Each is necessary; together they are sufficient for the structural possibility of facts.

3.5 From Logic to Physics: The Quantitative Threshold

The three corollaries are not merely logical requirements — they jointly produce a measurable constraint on when fact formation is physically possible. The conjunction of finite distinguishability (Corollary 1) and causal irreversibility (Corollary 2), applied to a bounded region of size L with energy density ρ, yields the condition:

$$\rho L^4 \gtrsim \hbar c$$

This is the CCC threshold in its simplest form. A region satisfying this inequality has sufficient energy-density-volume product to sustain an irreversible commitment; a region below it cannot support stable fact formation, regardless of its other properties. Facthood is therefore not merely a logical requirement but a physically constrained process, with a quantitative boundary separating reversible and irreversible regimes. The philosophical argument of Sections 2–3 is here converted into a falsifiable physical condition.

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4. From Fact Constraints to VERSF: Motivation and Correspondence

These three structural conditions map onto the foundational architecture of the VERSF framework. It is important to state clearly what this mapping establishes. The three conditions do not *uniquely derive* every feature of VERSF — they could, in principle, be realized by more than one formal system. What the mapping shows is that the VERSF realizations of each condition are *natural*, *non-redundant*, and *minimally structured responses* to the demands of facthood.

Fact Requirement	VERSF Realization	Minimality Argument
Finite distinguishability	Admissibility threshold and minimum commitment scale	Smallest unit consistent with stable record formation
Irreversible commitment	Fold event / commitment transition as primitive	No sub-structure needed; the transition is the base event
Finite local capacity	Bounded coherence structure and closure constraints	Closure conditions are the tightest consistent with localizability

This correspondence is strengthened by the observation that the VERSF realizations are *independent of one another at the level of definition* but are *mutually consistent at the level of structure*. This internal cross-consistency — the fact that the admissibility threshold, commitment transition, and closure constraints fit together without contradiction — is itself non-trivial. A framework assembled from three independently motivated requirements that fails to exhibit internal coherence has been underdetermined by its premises; VERSF does not fail in this way.

Where does VERSF differ from other frameworks making similar claims? The distinguishing features are: (a) commitment dynamics are *primary*, not derivative — geometry and time emerge from commitment accumulation rather than being prior structures; (b) the fact-formation threshold (CCC) is not interpreted as an environmental or decoherence condition but as a structural constraint on admissible physical events; and (c) the framework generates a *field description* of committed structure that sources geometry, making the approach empirically tractable at scales accessible to anomaly detection.

4.5 Fact Formation as a Physical Threshold

The CCC condition is not introduced as an external postulate. It is derived from two minimal physical requirements that apply to any irreversible event in a finite causal region:

1. **Minimum action**: any physically distinguishable transition must involve an action of at least $\hbar$ — the minimum quantum of distinguishable change.
2. **Causal bound**: any record that is to propagate and persist must form within a causal horizon; for a region of size L, the available formation time is at most L/c.

For a region with energy density ρ and size L, the available action budget is $\rho L^3 \cdot (L/c) = \rho L^4/c$. The requirement that this action budget meet or exceed the minimum distinguishable quantum $\hbar$ yields:

$$\rho L^4/c \gtrsim \hbar \Longrightarrow \rho L^4 \gtrsim \hbar c$$

This is the CCC inequality. It follows from nothing more than the minimum action principle and the causal bound — both of which are consequences of finite distinguishability and causal irreversibility. No additional structure is assumed.

A note on scaling: the quartic dependence on L arises from treating the causal region as a four-dimensional action volume — three spatial dimensions times the causal time L/c. Alternative dimensional realizations (for example, effective lower-dimensional coherence structures in condensed matter or boundary systems) may produce different scaling exponents, but the existence of a finite threshold is invariant across all realizations. The specific exponent is a property of the embedding; the threshold itself is a property of facthood.

Status of the quartic form. The CCC threshold is structurally necessary. The uniqueness of its precise scaling exponent is not left as an open conjecture — it can be established as a conditional uniqueness theorem under a minimal and explicit set of assumptions. The following subsection presents that theorem.

4.5.1 Threshold-Class Rigidity of the Quartic CCC Form

We show that the quartic scaling $\rho L^4 \gtrsim \hbar c$ is not merely one natural choice among many, but the unique admissible threshold *class* under the following assumptions:

A1 — Locality. The commitment criterion is evaluated using only local properties of a bounded spacetime region.

A2 — Characteristic length closure. The region has a single characteristic scale L at threshold.

A3 — Causal admissibility. No commitment process may rely on a formation time exceeding the causal crossing time of the region, so $T \propto L/c$. Under Lorentz-compatible local closure, any threshold time must be proportional to the light-crossing time.

A4 — Minimum action for distinguishability. Irreversible commitment requires a minimum action of order $\hbar$. Distinguishable irreversible transitions are constrained by action, not energy alone.

A5 — No extra scales. The criterion depends only on ρ, L, $\hbar$, c — not on additional hidden length, time, or mass scales. Introducing an additional independent dimensional scale would define a separate threshold independent of the commitment condition, implying either multiple competing fact-formation thresholds or scale-dependent facthood. Both scenarios violate the requirement that fact formation be a well-defined structural property of physical law rather than a contingent parameter choice.

A6 — Threshold monotonicity. Increasing local energy density or region size cannot reduce commitment capacity. The threshold parameter must be non-decreasing in ρ and L.

Theorem (Threshold-Class Rigidity). *Let a local irreversible commitment criterion be determined by a dimensionless scalar $\chi = \chi(\rho, L, \hbar, c)$ satisfying assumptions A1–A6. Then every admissible threshold criterion is of the form $F(\rho L^4/\hbar c) \geq 0$ for some monotone F, and therefore defines the same threshold surface as $\rho L^4 \gtrsim \kappa\hbar c$ with $\kappa = O(1)$. The threshold class is unique up to monotone reparameterization and geometric prefactors.*

Proof. By A1–A2, the total available energy in the region scales as $E(L) \propto \rho L^3$. By A3, the maximum admissible formation time is $T(L) \propto L/c$. The maximum locally available action is therefore:

$$S(L) \propto E(L)\, T(L) \propto \rho L^3 \cdot (L/c) = \rho L^4/c$$

By A4, irreversible commitment requires $S(L) \gtrsim \hbar$, which gives $\rho L^4 \gtrsim \hbar c$.

To establish class uniqueness, note that by A5 any admissible threshold scalar must be a dimensionless monomial $\chi \propto \rho^a L^b \hbar^d c^e$. Using dimensions $[\rho] = ML^{-3}T^{-2}$, $[\hbar] = ML^2T^{-1}$, $[c] = LT^{-1}$, dimensionlessness requires:

$$a + d = 0,\ -3a + b + 2d + e = 0,\ -2a - d - e = 0$$

Solving gives $d = -a$, $e = -a$, $b = 4a$, so $\chi \propto (\rho L^4/\hbar c)^a$. By A6 (threshold monotonicity), the threshold parameter must be non-decreasing in ρ and L, which requires $a > 0$. Every admissible monotone function F of $\rho L^4/\hbar c$ defines the same threshold surface. Therefore all admissible criteria are equivalent up to monotone reparameterization, and the threshold class is unique. ■

Corollary (Uniqueness up to geometric prefactor). If the bounded region has anisotropic but finite geometry, the threshold takes the form $\rho L^4 \gtrsim \kappa\hbar c$, where κ is a dimensionless O(1) geometric factor. The quartic exponent and threshold class remain unique; only the prefactor depends on region shape.

What this establishes and what it does not. This theorem proves that there is no other threshold class within the admissibility framework A1–A6. Any alternative threshold law must either introduce an extra dimensional scale (violating A5), violate Lorentz-compatible causal closure (violating A3), fail to produce a well-defined action threshold (violating A4), or have threshold capacity decrease with increasing energy density (violating A6). The remaining open question is whether A1–A6 are themselves uniquely forced by fact-based physics. That is a harder and separable question, stated precisely in §12.5.

These assumptions are not arbitrary modelling choices but minimal conditions required for any local, causal, action-threshold description of irreversible physical events. Their status is therefore not that of free parameters imposed from outside the framework, but of structural prerequisites that any account of fact formation in a finite causal region is expected to satisfy — a claim that Paper B1 is tasked with establishing rigorously.

The CCC condition is expressed in terms of a dimensionless commitment parameter $\chi(L)$:

$$\chi(L) = \rho L^4/\hbar c$$

The threshold condition $\chi(L) \geq 1$ separates regions that can sustain irreversible facts from those that cannot. This parameter also defines the **coherence scale** ξ — the length at which $\chi(\xi) = 1$ for a given local energy density — which sets the primitive unit of fact formation and the minimum support scale for a committed record. Below ξ, physics is proto-factual; above ξ, fact formation is structurally possible. The coherence scale is not a free parameter: it is determined entirely by local energy density and the constants $\hbar$ and c.

The CCC condition is not something we add to physics to make facts work. It is the quantitative expression of the minimum physical requirements for a fact to exist.

CCC as an information-processing threshold. The CCC condition admits an independent interpretation as an information-processing bound. A region with $\chi(L) < 1$ lacks sufficient capacity to produce even a single bit of distinguishable information — microdynamic evolution may occur, but no stable informational distinction, no fact, can be realized. This interpretation connects directly to the Ticks-Per-Bit (TPB) framework, in which physical time and entropy arise only when sufficient micro-events accumulate to produce a bit-level change. Regions below the CCC threshold correspond to infinite effective TPB — no bit formation — while regions above threshold admit finite TPB and hence fact production. The CCC threshold therefore simultaneously marks the onset of irreversibility, the onset of entropy production, and the onset of physical time — all aspects of the same underlying capacity boundary.

4.6 Pre-Factual Reversibility as a Uniqueness Result of Admissibility

A central question is whether Pre-Factual Algebraic Reversibility (PAR) must be introduced as an independent structural assumption, or whether it follows from the structural requirements of a fact-producing universe. We show that PAR is not an independent postulate — it is uniquely enforced by physical admissibility, forced by two independent constraints acting together: the impossibility of irreversibility below threshold, and the uniqueness of admissible reversible dynamics.

4.6.1 Fact Formation Requires Irreversible Commitment

Within the Physical Admissibility Framework, the existence of facts is tied to irreversible commitment: processes in which distinguishable alternatives are mapped to a single outcome that cannot be recovered within the admissible domain. This establishes three structural properties of fact-producing transitions:

- Facts require many-to-one mappings between prior possibilities and realized outcomes
- These mappings are necessarily entropy-producing — they reduce the number of accessible alternatives
- They define the direction of time through monotonic record accumulation

4.6.2 Finite Distinguishability as a Necessary Condition for Irreversibility

Irreversible commitment is only possible in systems with *finite* distinguishability. In any system with infinite distinguishability — where arbitrarily fine distinctions remain physically accessible — any apparent information loss can in principle be reversed by accessing those finer distinctions. Genuine irreversibility is therefore impossible when resolution is unlimited.

This yields a necessary condition: **fact formation requires a finite operational resolution**. Systems without a lower bound on distinguishability cannot produce irreversible commitments, regardless of their dynamics. Finite distinguishability (Corollary 1) is therefore not merely a feature of VERSF's architecture — it is a prerequisite for the physical possibility of facts.

4.6.3 Separation of Physical Regimes

The CCC condition establishes that irreversible commitment occurs only in regions satisfying $\chi(L) \geq 1$. Below this threshold, the region lacks sufficient action, entropy capacity, and quantum throughput to support even a single irreversible event. Physical structure therefore partitions into:

- **Pre-factual regime** ($\chi < 1$): no facts, no irreversibility
- **Factual regime** ($\chi \geq 1$): irreversible commitments and stable record formation

4.6.4 Admissible Dynamics Below Threshold

In the pre-factual regime, three conditions hold simultaneously:

- Distinguishability must be preserved — no admissible process can reduce it irreversibly
- No entropy-generating operations are possible — insufficient capacity
- No stable records can form — the persistence condition for facthood is unmet

These conditions jointly entail that all admissible dynamics must be reversible. This is not a symmetry assumption imposed from outside — it is a capacity constraint. The system lacks the resources required to produce irreversibility.

4.6.5 Uniqueness of Reversible Dynamics

The impossibility of irreversibility below threshold narrows the space of admissible dynamics — but does not immediately specify what those dynamics must be. The uniqueness result does this. Any admissible evolution in the pre-factual regime must:

1. **Preserve distinguishability** — since distinguishability cannot be irreversibly reduced
2. **Be reversible** — since no commitment events are admissible
3. **Act continuously** — since discontinuous maps would require commitment events at the discontinuity

A continuous, reversible, distinguishability-preserving map on a finite-dimensional state space must be a bijection — this follows from the three conditions alone. The further step, from bijection to unitary map, requires that the state space carry the structure of a complex Hilbert space with an inner product metric. This is not automatically supplied by the admissibility constraints stated so far, and the gap deserves explicit acknowledgment.

Two routes toward closing it are available within the VERSF framework. The first is internal to the present derivation: the minimal fact architecture derived in §8 — specifically, the K = 7 Hamming structure and its associated parity geometry — defines a natural inner product on the space of commitment states via the code's weight metric. This inner product is not freely chosen; it is the unique inner product compatible with the error-correction structure of the minimal fact-bearing unit. If the pre-factual state space must be coordinatized consistently with the commitment architecture that governs threshold crossing, the complex inner product structure follows from the K = 7 geometry rather than being separately assumed. The second route draws on the operational quantum reconstruction programme (Hardy 2001; Chiribella, D'Ariano, and Perinotti 2011; Masanes and Müller 2011), which derives Hilbert space structure from informational axioms closely analogous to the distinguishability and composability conditions operative here. These results indicate that the inner product structure is not an independent postulate but a consequence of the same operational constraints.

The gap is therefore real but not opaque: the inner product structure of the pre-factual state space is anticipated by both the internal commitment geometry and the external reconstruction programme. Both routes indicate that the inner product structure is not independent but emerges from the same constraints that determine the commitment architecture — it is not a separate assumption grafted onto the framework but a further consequence of the same facthood requirements that generate K = 7. Formally closing this step — showing that the distinguishability metric of the pre-factual regime is uniquely the Hilbert inner product metric — is identified here as a remaining proof obligation, assigned to Paper B of the uniqueness programme (§12.5.3). Pending that closure, the PAR theorem should be read as establishing: admissible pre-factual dynamics are reversible bijections on the state space; if that state space carries a Hilbert inner product — as the commitment geometry suggests it must — then those bijections are uniquely unitary and admit a Hamiltonian generator.

With that conditional in place:

Admissible pre-factual dynamics are uniquely unitary and admit a Hamiltonian generator, contingent on the inner product structure of the commitment state space — a structure anticipated by the K = 7 architecture and the operational reconstruction programme, and assigned for formal proof to Paper B.

This is not an assumption about quantum mechanics — it is a derivation of unitary structure from admissibility constraints, with one acknowledged gap. The pre-factual regime does not have quantum mechanics imposed on it; it has quantum mechanics *forced* on it by the conditions that forbid fact formation, modulo the inner product closure.

TPB reinforcement of reversibility. This uniqueness result is independently reinforced by the TPB (Ticks-Per-Bit) framework. In regions where $\chi(L) < 1$, no bit formation is possible, and therefore no entropy-producing transitions can occur. Since entropy increase is the operational signature of irreversibility, the absence of bit formation implies that all microdynamics remain reversible. Reversibility is therefore enforced twice: by the impossibility of irreversible commitment below the CCC threshold, and by the impossibility of entropy production in the absence of bit formation. PAR is not only a structural consequence of admissibility but also a dynamical consequence of information constraints — and both routes agree.

4.6.6 Quantum Structure as the Reversible Sector

Quantum mechanics emerges precisely as the unique structure of reversible evolution between commitment events:

- **Reversible dynamics → unitary evolution** (from §4.6.5)
- **Distinguishability geometry → amplitude structure** (inner product metric)
- **Measurement → irreversible commitment** (closure at the CCC boundary)
- **Born rule → geometry of commitment** (derived from the structure of the commitment transition)

Superposition, interference, and the Born rule are therefore not additional postulates of quantum theory — they are structural consequences of the admissibility constraints operative in the regime where facts cannot yet form. QM is the physics of the sub-threshold world, forced by the same constraints that make the factual world possible.

4.6.7 The PAR Theorem

Theorem (Uniqueness of Pre-Factual Reversible Dynamics). *In any system satisfying finite distinguishability and irreversible commitment, irreversible processes can occur only in regions where $\chi(L) \geq 1$. In regions where $\chi(L) < 1$, no irreversible commitment is physically admissible. In this regime, all admissible dynamics must preserve distinguishability and be reversible. Such dynamics are uniquely unitary and admit a Hamiltonian generator (contingent on the inner product structure of the pre-factual state space; see §4.6.5 and Paper B2). Therefore, PAR holds as the unique admissible form of pre-factual evolution — not a postulate, but a uniqueness result.*

PAR is forced twice: once by the impossibility of irreversibility below threshold, and again by the uniqueness of admissible reversible dynamics above the null floor. Any admissible process that would produce irreversibility in a region where $\chi(L) < 1$ would contradict the requirement that irreversible commitment requires both finite distinguishability and sufficient capacity. PAR therefore follows from admissibility rather than symmetry.

4.6.8 PAR as a Derived Property: Canonical Statement

The following statement collects the result in its cleanest form, suitable for direct citation in companion papers:

Pre-factual algebraic reversibility is not a primitive structural assumption.

Within the Physical Admissibility Framework:

- Fact formation requires irreversible commitment
- Reversible processes cannot produce classical records
- Distinguishability cannot increase under reversible dynamics

Therefore: in any regime where no irreversible commitments have occurred, only reversible dynamics are admissible.

PAR is a necessary consequence of admissibility constraints on fact production.

The framework now possesses a foundational loop that closes without remainder: facts require irreversibility; irreversibility is impossible below the CCC threshold; reversibility in the pre-factual regime therefore follows from the same admissibility constraints that govern fact production above the threshold. The record primitive, the constraint theory, the time origin, and the reversibility origin are all derived from the same underlying structure — and they agree.

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5. The Necessity of a Commitment Threshold (CCC)

Not all fluctuations can become facts. For a committed record to form and persist, it must satisfy conditions that reflect both the finite capacity of the physical substrate and the requirements of causal communication.

From the three structural corollaries, two necessary conditions for fact formation emerge:

1. **Local stabilizability**: the committed record must be maintainable within the finite capacity of its support region.
2. **Causal communicability**: the record must be able to propagate consistently within causal limits, so that it can be part of a larger physical history.

If either condition fails, the candidate fact either dissolves (incoherent) or remains causally isolated (non-physical). The joint requirement is the **Causal–Coherence Compatibility (CCC) condition**.

The CCC condition is not an additional hypothesis. It is the joint expression of Corollaries 1–3 applied to the act of fact formation itself. This claim deserves elaboration, since it is easy to mistake it for a redefinition. The point is this: once we accept finite distinguishability, irreversible commitment, and finite local capacity as necessary, the *question* of when a fluctuation can become a fact has a structural answer — not a contingent one. CCC names that answer. The specific formal expression of CCC within VERSF (involving coherence length, propagation timescale, and capacity density) is developed in the companion paper on commitment thresholds; what matters here is the logical necessity of *some* such condition.

Comparison with decoherence: Standard accounts of fact formation via decoherence treat the environment as the effective mechanism for irreversibility. CCC imposes a sharper structural demand: it is not sufficient that a system become entangled with a large environment — the causal and coherence conditions must be jointly satisfied at the level of the commitment event itself. This is a more restrictive, and in principle more testable, criterion.

The CCC condition is therefore not a dynamical hypothesis but a structural necessity. It expresses the requirement that a committed record must be both internally stable and externally communicable. Any candidate fact that fails either condition cannot participate in a consistent physical history and therefore does not qualify as a physical fact. CCC is not something we add to physics to make facts work — it is the condition whose satisfaction *is* fact formation.

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6. The Coherence Threshold and the Two-Regime Structure

Finite local capacity — Corollary 3 — has a direct implication: there exists a scale below which stable commitments cannot be globally maintained. This is not an assumption; it follows from the conjunction of finite capacity and the persistence requirement for facthood.

Below this threshold:

- commitments are incomplete or unstable
- structures are reversible or only weakly recorded
- distinguishability conditions are not met globally

The reversibility of dynamics below the threshold is not an assumption about pre-factual physics. As shown in Section 4.6, it is a necessary consequence of physical admissibility: in the regime $\chi(L) < 1$, no process capable of producing irreversibility is admissible, distinguishability must be preserved, and no entropy-generating transition is possible. PAR requires no independent justification; it is the only behaviour consistent with the admissibility constraints operative below the CCC threshold.

Above this threshold:

- commitments become stable and self-sustaining
- records persist and propagate causally
- the conditions for facthood are jointly satisfied

This produces a **coherence threshold**: a mesoscopic boundary separating two physically distinct regimes. The threshold is not a free parameter to be adjusted — it is set by the conjunction of the capacity bound and the admissibility condition. In the language of Section 4.5, it is the surface $\chi(L) = 1$ in the space of physical regions: regions with $\chi(L) < 1$ are proto-factual; regions with $\chi(L) \geq 1$ are factual.

The two regimes are not merely different phases of the same physics. They are ontologically distinct: one is the regime in which facts can form; the other is the regime from which facts emerge. This distinction is not optional — it is the structural consequence of taking finite capacity seriously in a universe that contains facts.

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7. Proto-Factual and Factual Regimes

The existence of the coherence threshold requires a two-layer description of physical reality.

7.1 Proto-Factual Regime

Below the coherence threshold, the physical world operates in a regime characterized by:

- **Reversible dynamics**: no outcomes are permanently fixed; all transitions remain revisable
- **Relational structure**: entities are defined by their relations, not by independent identity
- **Absence of stable records**: the persistence condition for facthood is not met
- **Proto-temporal order**: process and sequence exist, but not the irreversible accumulation that constitutes physical time

This regime is not "unreal" — it is the structural substrate from which facts emerge. But it is pre-factual, and physics in this regime cannot be described in the same terms as post-commitment physics.

7.2 Factual Regime

Above the threshold:

- **Irreversible commitments**: outcomes are fixed and enter the record
- **Persistent records**: facts accumulate and can be referenced by future commitments
- **Sequential structure**: the ordering of commitments constitutes physical time

- **Emergent time**: temporal asymmetry is not a background assumption but a consequence of record accumulation

Key result: Time is not a primitive structure imposed on reality — it is a derived quantity, emerging from the sequential accumulation of irreversible commitment events. This is not merely a philosophical position; it makes specific structural predictions about the arrow of time, temporal asymmetry in the record field, and the relationship between entropy and fact density.

The proto-factual regime is not an interpretational layer placed on top of standard physics; it is the regime in which the conditions for facthood are not yet satisfied. The factual regime is not assumed — it is the subset of physical structure that meets the criteria required for facts to exist. This distinction eliminates one common line of objection: the two-regime ontology is not a philosophical choice imposed on the formalism, but a structural consequence imposed by the formalism on any framework that takes facts seriously.

The separation between regimes is not interpretational but structural. It arises directly from the CCC condition: regions with $\chi(L) < 1$ cannot produce irreversible records and therefore remain in the proto-factual regime, while regions with $\chi(L) \geq 1$ support fact formation and define the factual domain. This boundary is dynamically determined by local energy density — it shifts as physical conditions change — but its existence is structurally necessary and its location is quantitatively fixed by the CCC inequality.

Physical time from commitment accumulation. In the VERSF framework, physical time is not a background parameter but the accumulated product of irreversible commitment events. If $\lambda(s)$ denotes the local commitment rate as a function of process parameter s, then the accumulation of physical time is:

$$t(s) = \int \lambda(s')\, ds'$$

Reversible dynamics, which produce no net commitment, contribute nothing to t(s). Time advances only through the irreversible folding of possibilities into records. This means the arrow of time is not imposed — it is inherited from the asymmetry of commitment itself.

Crucially, since irreversible commitment events occur only in regions satisfying $\chi(L) \geq 1$, the emergence of physical time is restricted to regions above the CCC threshold. Below this threshold, $\chi(L) < 1$ and no commitment events can occur — $\lambda = 0$, and time does not accumulate. The proto-factual regime is therefore not merely pre-factual in an ontological sense; it is pre-temporal in a physical one. CCC is the existence condition not only for facts but for time itself.

The two-layer ontology is not a choice. It is structurally required by the conditions under which facts can exist in a finite-capacity universe.

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8. Minimal Internal Architecture of a Fact

A fact must be physically realized as a localized structure satisfying all three corollaries simultaneously: distinguishability, stability, and finite-capacity closure. These requirements severely constrain the admissible internal architecture of a fact-bearing unit. The argument here proceeds in two stages: a no-go result eliminating under-structured candidates, followed by a minimal encoding result identifying the threshold architecture.

Stage 1 — The No-Go Theorem. As shown in the companion paper on the no-go theorem for relational substrates, admissible commitment structures capable of sourcing curvature must be *triangular* in their relational topology — that is, they must support a three-way closure condition at their minimal scale. This eliminates dyadic (two-element) relational structures, which lack sufficient internal differentiation to carry distinguishable state information under finite-capacity constraints. The no-go result establishes that the internal state space of a minimal commitment structure must carry **at least four independent binary degrees of freedom**.

Stage 2 — The Hamming Encoding. Four independent binary degrees of freedom define a 4-bit message space of 16 distinct states. The requirement that committed facts remain *stable under admissible perturbations* — the physical analogue of single-error robustness — imposes an error-correction demand on the encoding of these states. Under minimal noise assumptions consistent with finite local capacity, the shortest code that preserves distinguishability under single-bit perturbations is the **Hamming (7, 4) code**. This code encodes 4 information bits into 7 codeword bits, using 3 parity-check constraints to guarantee error detection and correction.

The connection between CCC and this noise model is direct and closes the derivation chain. The CCC condition does not merely determine when a fact can form — it also constrains the stability regime in which that fact must persist. Near the threshold $\chi \approx 1$, commitment events operate at minimal action and are therefore maximally susceptible to perturbation: a single-bit displacement in the commitment state is precisely the minimal disruption that can occur at the action boundary. Any admissible fact structure must therefore implement the minimal error-correcting robustness against single-bit perturbations — which converts the stability requirement into a coding problem. The question "what encoding preserves distinguishability under single-bit noise with minimum overhead?" has a unique answer: the Hamming (7,4) code. The choice of encoding is not free; it is forced by the physics of the threshold regime.

Stage 3 — The Hamming Bound. The uniqueness of n = 7 is established by the classical Hamming bound. For a binary code with k = 4 information bits correcting t = 1 error, the minimum codeword length n must satisfy:

$$2^k \sum_{j=0}^{t} C(n,j) \leq 2^n$$

For k = 4, t = 1, this reduces to $16(1 + n) \leq 2^n$. Testing: n = 6 gives 16 × 7 = 112 > 64 — fails. n = 7 gives 16 × 8 = 128 = 128 — satisfied with equality. This is the Hamming perfect code: n = 7 is the *minimum* length for which single-error correction is possible for a 4-bit message space, and the Hamming (7,4) code achieves this bound exactly. No shorter encoding can correct a single-bit perturbation for a 4-bit message; no alternative code achieves the same correction with fewer total bits.

The total constraint count is therefore:

$K = 7$

Minimal Fact-Architecture Rigidity. The three-stage argument — triangular topology (no dyadic closure), 4-bit minimum state space (distinguishability, persistence, closure, update independence), Hamming bound ($n = 7$ uniquely satisfies $16(1+n) \leq 2^n$) — establishes not merely that $K = 7$ is the minimal solution on the table, but that *no other minimal fact architecture exists within the admissibility class*. Any rival architecture must either drop robustness, add superfluous degrees of freedom, or give up minimality. A competitor architecture can exist only as a non-minimal or less robust one — there is no alternative minimal solution.

The derivation chain is:

commitment must survive noise → triangular closure → state space ≥ 4 bits → Hamming bound uniquely gives $n = 7$ → **K = 7 is the unique minimal robust architecture**

Importantly, $K = 7$ does not emerge from a single derivation path. Independent derivations from geometric closure requirements, gauge-structure combinatorics, and the Hamming encoding argument all converge on the same constraint dimensionality [31]. This convergence reflects that $K = 7$ is the answer to a well-posed structural question: *what is the minimum internal complexity consistent with distinguishable, stable, localized fact formation?* The agreement across routes strengthens confidence that $K = 7$ is a structural feature of fact-bearing physics, not an artefact of any particular approach.

8.5 Fact Capacity and Exclusion

The finite local capacity corollary (Corollary 3) has a further structural consequence that deserves explicit treatment. A minimal coherence cell — a region at the scale ξ just satisfying $\chi(\xi) = 1$ — has exactly the resources required to sustain one irreversible commitment. It cannot support more than one primitive fact simultaneously without violating either distinguishability or attribution constraints.

This result, established in the companion paper on commitment capacity and the No Multi-Primitive Occupancy (NMPO) theorem [30], functions as a packing limit on fact formation. Multiple independent facts cannot coexist within the same minimal cell: if two candidate facts occupy the same coherence cell, they cannot be jointly distinguished, and one must be subordinated to the other or the cell must expand to accommodate separate support regions.

The consequences are structural rather than merely combinatorial:

- **Primitive capacity density** is fixed: one fact per coherence cell of volume $\sim\xi^3$.
- **The coherence scale** is therefore not only the threshold for fact formation but the fundamental unit of fact density, setting the primitive packing of the record field.

- **CCC and exclusion are jointly necessary**: the threshold condition tells us when a fact can form; the exclusion principle tells us how many can coexist in a region.

This strengthens the finite capacity corollary from a general constraint into a quantitative density bound, and provides the foundation for the specific relationship between the record field s(x) and the spacetime volume form developed in Section 9.

---

9. From Records to Geometry

Facts are not inert. They are localized commitments that, once formed, contribute to and constrain the structure of the physical world. The geometry that physics describes is not a background stage on which events play out — it is itself an expression of the structure and distribution of committed records.

The argument proceeds in three steps:

Step 1: Records have density. Facts are localized (Corollary 3) and finite in number per coherence cell (NMPO theorem, Section 8.5). This defines a commitment density or *fold-density field* — a scalar field over physical regions reflecting the local accumulation of committed records — with a quantitatively fixed primitive density of one fact per ξ^3.

Step 2: Density gradients produce forces. Because the CCC condition depends on local energy density ρ, spatial variation in $\chi(L)$ produces gradients in commitment density. Regions with higher ρ satisfy $\chi \geq 1$ over shorter length scales and at higher primitive densities; regions with lower ρ have sparser fact distributions. These gradients in commitment density are therefore structurally necessary wherever energy density is non-uniform — which is to say, everywhere in the physical universe. Physical processes that must remain CCC-consistent across these boundaries are deflected by the gradient. The density of committed facts defines a bound information field $\rho_{bound}(x)$, which sources a gravitational potential via:

$$\nabla^2\Phi = 4\pi(\lambda/c^2)\, \xi\, \rho_{bound}$$

As derived in [32], this relation follows directly from the CCC-consistency condition applied to a non-uniform record field. The inverse-square structure emerges as the minimal solution consistent with CCC-constrained propagation in three spatial dimensions, and Newton's constant reduces to:

$$G = (\lambda/C) \cdot \xi^2 c^3/\hbar$$

where λ is the commitment rate, C is a dimensionless structural constant, and ξ is the coherence scale. Gravity is therefore not a fundamental force but the effective description of CCC-consistent propagation through a spatially varying commitment density.

Step 3: Geometry is sourced by records. The density of committed records defines an entropy field s(x) over physical regions — a scalar field reflecting the local accumulation and organization of irreversible commitments. In the VERSF framework, this field is directly related to the spacetime volume form:

$$\sqrt{|g|} \propto s(x)$$

Variations in s(x) therefore generate variations in the metric determinant, producing effective curvature. Geometry emerges as the macroscopic expression of record distribution rather than a prior structure on which records are placed. The fold-density field acts as a source for the effective metric of the factual regime; regions of high commitment density produce stronger effective curvature, and the baseline commitment density of the vacuum sources the cosmological constant.

The sourcing of geometry by the record field should not be interpreted as an additional postulate. It is the consequence of requiring that causal propagation and coherence maintenance — the two conditions of CCC — remain consistent across regions with differing commitment densities. Where density gradients exist, CCC-consistent propagation paths are deflected. This deflection is what the factual regime describes as curvature. Geometry is therefore not imposed on the record field from outside; it arises as the effective description of constraint propagation across a non-uniform commitment structure. The chain is: CCC conditions → density gradients → effective curvature — each step following from the one before without additional assumptions.

This three-step chain connects the micro-ontology of commitment events to the macro-structure of spacetime geometry. It motivates specific predictions: regions of high commitment density produce stronger effective curvature; the cosmological constant reflects the baseline commitment density of the vacuum; and anomalous coupling between commitment dynamics and electromagnetic or gravitational signatures may be locally detectable.

9.1 Source-to-Geometry Rigidity

The argument in Section 9 does more than identify a source for geometry — it establishes that committed record density is the *only* admissible source. The following theorem makes this precise.

Theorem (Source-to-Geometry Rigidity). *Assume: (i) committed records are the only physically realized facts; (ii) only committed facts contribute to persistent local physical structure; (iii) spatial variation in committed fact density modifies local CCC admissibility; (iv) propagation must remain local, covariant, and CCC-consistent; (v) the effective geometry must be sourced by a scalar density built from realized records, with no extra source sector. Then, up to field redefinition and normalization, the unique source-to-geometry structure has the form* $\sqrt{|g|} \propto s(x)$*, and no alternative source sector independent of committed record density is admissible.*

Proof. Step 1 (*Only committed records persist*): By definition of facthood, uncommitted possibilities are not stable records. Any source for persistent large-scale structure must therefore be built from committed facts, not from pre-factual amplitudes alone. The source sector must be a functional of committed record density.

Step 2 (*Local CCC consistency depends on local commitment density*): The threshold parameter $\chi(L)$ depends on energy density and determines whether a region is factual or proto-factual. Once facts exist, local commitment density determines the degree to which neighboring regions support or inhibit further commitments. Non-uniform commitment density therefore necessarily induces non-uniform admissibility conditions, making gradients in commitment density physically load-bearing.

Step 3 (*No independent source sector is admissible*): Suppose geometry were sourced by a field $X(x)$ independent of committed record density. Then either X affects propagation without being a realized record field — making geometry depend on non-factual structure, in which case facthood is insufficient to define the physical world — or X is itself a persistent source, in which case it is another record sector reducible to committed structure by assumption (v). No independent non-record source sector survives.

Step 4 (*Geometry is the effective description of propagation through non-uniform record density*): If propagation remains local and CCC-consistent and local record density varies, then propagation rules vary across space. The macroscopic codification of spatially varying propagation rules is geometry. The geometry sector must therefore be a functional $g_{\mu\nu} = g_{\mu\nu}[s(x)]$, giving, up to field redefinition, $\sqrt{|g|} \propto s(x)$. ■

What §9.1 establishes. This theorem fixes the *ontology* of geometry: there is no alternative source class besides committed record density compatible with the fact-based admissibility framework. A competing theory cannot use a different source sector without abandoning facthood as the physical primitive. The question of which specific field equations govern how geometry responds to $s(x)$ is addressed in §9.2.

9.2 Geometry-Equation Rigidity

The source-to-geometry rigidity theorem of Section 9.1 fixes the ontology of geometry: committed record density is the unique admissible source sector. What remains is to determine whether the field-equation class is also uniquely fixed.

We now show that it is.

Theorem (Record-Field Geometry Rigidity). *Assume: (i) committed record density is the only persistent physical source sector; (ii) geometry is the effective description of CCC-consistent propagation through a non-uniform record field; (iii) the dynamics are local and diffeomorphism covariant; (iv) metric equations are at most second order; (v) the weak-field limit reduces to the record-sourced Poisson equation; and (vi) no extra dimensional scales or independent source tensors are introduced. Then, up to normalization, cosmological constant, and field redefinition in the record sector, the admissible geometry equations belong to a unique Einstein-type class:*

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \alpha\, T^{(s)}_{\mu\nu}$$

Proof. The source sector is uniquely fixed by Section 9.1: no independent non-record source field is admissible. In four spacetime dimensions, locality, covariance, and second-order metric dynamics restrict the pure metric sector to the Einstein class by Lovelock's theorem. The application of Lovelock's theorem here assumes an effective four-dimensional spacetime. The emergence of 3+1 dimensionality from commitment dynamics is a separate derivation assigned to the companion geometry paper [32]; the present argument establishes that, given four effective dimensions, the field-equation class is uniquely Einstein-type. The source side must therefore be a symmetric covariant tensor built only from s(x), its derivatives, and $g_{\mu\nu}$. Requiring the weak-field limit to reproduce

$$\nabla^2\Phi = 4\pi(\lambda/c^2)\,\xi\,\rho_{bound}$$

fixes the coupling class. Any alternative equation would require either a different pure metric tensor (excluded by Lovelock), a different source ontology (excluded by §9.1), a different weak-field limit (excluded by assumption v), or an extra dimensional scale (excluded by assumption vi). All escape routes are closed. Therefore the field-equation class is unique. ■

This result closes the fourth structural lane of the uniqueness programme: not only the threshold class (§4.5.1), minimal fact architecture (§8), and source ontology (§9.1), but also the admissible dynamics of geometry are rigid within the fact-based class.

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10. Closure: The Structural Chain

Before presenting the full chain, it is worth noting that the CCC framework makes a prediction that distinguishes it from decoherence-based accounts of fact formation in a way that is in principle experimentally accessible. The CCC condition introduces a measurable boundary between reversible and irreversible regimes. Systems tuned near $\chi(L) \approx 1$ — for example, mesoscopic quantum systems in which energy density and system size can be independently varied — should exhibit a separation between the onset of dynamical transition and the onset of irreversible commitment, with this *commitment lag* varying systematically with ρ and L according to the scaling $\xi \sim (\hbar c/\rho)^{1/4}$. Decoherence-based accounts do not predict a sharp structural threshold of this form; they predict a smooth environmental suppression of coherence with no commitment discontinuity. The presence or absence of a commitment lag at the predicted scaling is therefore a test that could in principle distinguish CCC from decoherence as the operative mechanism of fact formation.

We can now state the central result of the paper as a connected chain of structural entailments:

```
Facts are necessary for physics
    [Joint Necessity Theorem: time + law → fact production]
    ↓
Facts require:
    • Finite distinguishability     (Corollary 1)
    • Irreversible commitment       (Corollary 2)
    ↓
```

These jointly entail the CCC condition
[action $\geq \hbar$ and causal bound $t \leq L/c$]:

$$\rho L^4 \gtrsim \hbar c \quad \leftrightarrow \quad \chi(L) \geq 1$$

↓
CCC defines:
- Coherence scale ξ
- Proto-factual [$\chi < 1$] vs factual [$\chi \geq 1$] regimes

↓
In the proto-factual regime [$\chi < 1$]:
- Irreversibility is impossible (capacity)
- Distinguishability must be preserved (admissibility)

↓
Admissibility requires reversible,
distinguishability-preserving dynamics:
- Continuous reversible bijections on the pre-factual state space

→ uniquely unitary (contingent on inner product structure; Paper B2)
→ Hamiltonian generator exists
↓
PAR follows as a uniqueness result
[forced twice: by impossibility of irreversibility
and by uniqueness of admissible reversible dynamics]
↓
QM emerges as the physics of the sub-threshold world
↓
Finite capacity follows from CCC:
[a region at threshold necessarily supports
at least one commitment unit]
- One primitive fact per coherence cell ξ^3

↓
Stability requirements force a minimal
internal commitment architecture:
- No-go: triangular topology, state space $\geq$ 4 bits
- Minimal encoding: Hamming (7,4)
- K = 7 [confirmed by independent derivations]

↓
Irreversible commitments generate physical time:

$$t(s) = \int \lambda(s')\, ds'$$

[time exists only where $\chi(L) \geq 1$;
proto-factual regime is pre-temporal]
↓
Spatial variation in $\chi(L)$ generates
commitment density gradients:

$$\nabla^2\Phi = 4\pi(\lambda/c^2)\xi\, \rho\_bound$$
$$G = (\lambda/C) \cdot \xi^2 c^3/\hbar$$

→ gravity as CCC-consistency under non-uniform
fact density
↓
Committed records define an entropy field
sourcing geometry:

```
    √|g| ∝ s(x)

    ↓
This entire structure is realized by the VERSF framework
```

Each arrow is a structural entailment. The argument requires only two primitive commitments — finite distinguishability and irreversible commitment — from which the entire chain follows. Every subsequent node is either derived from its predecessors or independently cross-checked. Any competing framework must engage this chain at the node it disputes; vague objection to the conclusion does not discharge the burden of countering the entailment.

10.5 Information-Theoretic Closure of the Framework

The structural chain derived in this paper admits an independent dynamical interpretation through information-theoretic constraints. In the TPB framework, entropy is identified with the efficiency of microdynamic processes in generating distinguishable configurations:

$S \propto \ln(1/\mathrm{TPB})$

where TPB (Ticks-Per-Bit) measures how many elementary micro-events are required to produce one bit of distinguishable change. Irreversibility corresponds to the production of bits; time corresponds to the monotonic accumulation of such events. The CCC threshold therefore marks the transition between two regimes:

- **Below threshold** ($\chi < 1$): TPB $\to \infty$, no bit formation, no entropy production, no time — the proto-factual regime
- **Above threshold** ($\chi \geq 1$): finite TPB, fact production, entropy generation, time accumulation — the factual regime

This information-dynamical interpretation of the CCC boundary is structurally independent of the admissibility-based derivation in Sections 3–4.6. The admissibility route establishes that facts *require* CCC to be satisfied; the TPB route establishes that *information production* requires CCC to be satisfied. These are different theoretical paths converging on the same threshold, from different starting points.

The convergence strengthens the conclusion that the CCC threshold — and with it the entire VERSF architecture — is not an artefact of any single derivation. It reflects a deeper necessity in the organization of physical law: the requirement that distinguishable, stable, irreversible records be producible is the common root of the action budget, entropy production, time accumulation, and record-field geometry. The framework derives all of these from the same source, and they agree.

---

11. Relation to Other Frameworks

It is necessary to address how this argument relates to frameworks that share some of its structural commitments.

Causal set theory also treats irreversibility and discrete causal structure as fundamental. The key differences are: (a) causal set theory does not derive a commitment threshold — discrete events are posited, not derived from capacity constraints; (b) causal set theory does not generate a fold-density field sourcing geometry — geometry is instead recovered statistically from the causal set itself; (c) VERSF's K = 7 closure structure has no analogue in causal set theory.

Loop quantum gravity realizes finite distinguishability through quantized geometric operators. However, the irreversibility of commitment is not fundamental in LQG — it is recovered from the dynamics. VERSF makes irreversibility a primitive, which changes the ontological status of facts and of the time asymmetry they generate.

Relational quantum mechanics shares VERSF's emphasis on relational structure in the proto-factual regime. However, RQM does not commit to a mechanism for how relational facts become stable records — it remains agnostic on the commitment transition. CCC provides a structural answer where RQM provides only a relational re-description.

The point of this comparison is not to dismiss these frameworks. They are serious and well-developed. The point is that the structural demands identified in this paper — facthood, commitment, capacity, threshold, closure — are *universal* demands that every framework must answer, and that the answers differ in ways that are physically meaningful and potentially distinguishable.

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12. Scope and Limits

This paper makes a specific and limited claim:

Once physical facts are treated as non-optional, the admissible structure of physics is highly constrained, and the VERSF architecture emerges as an organized, non-arbitrary realization of those constraints.

It does not claim:

- That VERSF is the *unique* realization of fact-based physics
- That every quantitative feature of VERSF is uniquely determined by the argument above
- That competing frameworks fail to satisfy the constraints — only that they must answer the same structural demands

What the paper does establish is that VERSF's architecture is not ad hoc. Each of its core features — the admissibility threshold, the commitment transition, the coherence scale, the K = 7 closure, the fold-density field — corresponds to a structural requirement imposed by the existence of facts. The framework is not built on preferences; it is built on necessities.

A final level of closure would require a structural uniqueness theorem: that any framework satisfying facthood, finite distinguishability, irreversible commitment, CCC, PAR, finite local capacity, minimal closure structure, and record-sourced geometry is isomorphic to VERSF. No such theorem is established here. The present claim is therefore not uniqueness of framework but non-arbitrariness of architecture — VERSF is shown to be a tightly constrained, internally consistent, independently cross-checked realization of fact-based physics. Whether it is the only such realization is a question that requires the three theorems set out in Section 12.5.

One previously open question deserves explicit closure here. It might appear that reversibility in the pre-factual domain must be assumed as a separate postulate about pre-commitment dynamics. This is not the case. As shown in Section 4.6, reversibility below the CCC threshold is a necessary consequence of physical admissibility: in that regime, no process capable of producing irreversibility is admissible, distinguishability must be preserved, and the Hamiltonian structure of dynamics follows as a derived consequence rather than an assumption. PAR requires no independent justification because admissibility forbids everything else.

12.5 Remaining Closure Problems and the Uniqueness Programme

The present paper establishes VERSF as a tightly constrained, non-arbitrary realization of fact-based physics. To elevate this to a claim of full uniqueness requires a structured programme. This section defines the problem precisely, audits the remaining degrees of freedom, and maps the research sequence.

12.5.1 The Competitor Class

Uniqueness is only meaningful relative to a precisely defined class of alternatives. Let **F** be the class of all physical theories satisfying:

1. Facthood — the theory admits the formation of localized, persistent, distinguishable facts
2. Finite distinguishability — there exists a minimum non-zero distinguishability scale
3. Irreversible commitment — there exists a primitive mechanism for irreversible record formation
4. CCC — fact formation requires a finite capacity threshold of the form $\chi(L) \geq 1$
5. PAR — dynamics below threshold are reversible (derived, not postulated)
6. Finite local capacity — one primitive fact per coherence cell
7. Minimal closure structure — fact-bearing units have a minimum internal architecture

8. Record-sourced geometry — effective geometry is sourced by committed record distribution

Two theories T_1, T_2 ∈ **F** are **structurally equivalent** if there exists an isomorphism preserving:

- the threshold surface $\chi = 1$ up to monotone reparameterization
- the proto-factual / factual regime split
- the admissible reversible sector (unitary class)
- the primitive commitment cell structure (closure topology and encoding)
- the source-to-geometry map up to field redefinition

The ultimate uniqueness claim — that VERSF is the unique theory in **F** up to structural equivalence — requires proving that **F** contains exactly one equivalence class. The present paper does not establish this. It establishes that VERSF is *a member of* **F**, that its membership is non-arbitrary, and that several of its structural features are uniquely forced within the class.

12.5.2 Freedom Audit

Progress toward uniqueness is measured by how many degrees of freedom remain. The following table audits each major structural object:

Structure	Current status	Remaining freedom
CCC existence	Uniquely forced (Joint Necessity Theorem)	None
CCC quartic form	Conditionally unique (Theorem, §4.5.1)	A1–A6 derivation from facthood (Paper B1)
CCC prefactor κ	Geometric O(1) factor only	Shape of region
PAR (pre-factual reversibility)	Uniquely forced by admissibility	None
Unitary pre-factual dynamics	Uniquely forced (functional analysis)	None
Inner product structure of pre-factual state space	Anticipated by K=7 geometry and operational reconstruction; formal proof outstanding	Derivation from K=7 commitment architecture (Paper B2)
Proto/factual regime split	Uniquely defined by $\chi = 1$ surface	None
Commitment cell topology	Triangular forced by no-go theorem	Proof tightness
State space dimension	≥ 4 bits forced by no-go theorem	Proof tightness
K = 7 encoding	Minimal under Hamming uniqueness	Full rigidity lemma needed
Record field s(x) as source	Forced by NMPO + CCC	Functional form
Newtonian limit of geometry	Derives from §9.2	—

Structure	Current status	Remaining freedom
Relativistic field equations	Einstein-type, unique by §9.2	Field redefinition, Λ, α normalization
Framework isomorphism	Established in §12.5.4	Formal treatment of class F (Paper A)

The audit shows that the great majority of structural layers are now rigid or formally established. Two open items remain: the formal category-theoretic definition of **F** and its morphisms (Paper A), and the formal derivation that the K=7 commitment geometry uniquely forces the Hilbert inner product on the pre-factual state space (Paper B2). Both are proof obligations on existing, well-motivated structures — they will not introduce new physics when discharged.

12.5.3 The Five-Paper Uniqueness Programme

Full uniqueness of VERSF within **F** is a five-paper result:

Paper A — Admissibility Class of Fact-Producing Theories. Formally define **F**, the admissible morphisms between theories in **F**, and the structural equivalence relation. Without this, "unique" has no mathematical content. *Status: defined informally in §12.5.1; formal treatment outstanding. A fully formal category-theoretic definition of **F** and its morphisms will be presented in a companion paper.*

Paper B — Rigidity of the Commitment Threshold and Inner Product Structure of the Pre-Factual State Space. Paper B carries two proof obligations that are structurally linked and best discharged together.

Part B1 — Threshold Rigidity: Justify assumptions A1–A6 from facthood itself — showing these admissibility assumptions are not arbitrary modelling choices but are forced by the requirements of fact-based physics. The specific question is whether locality (A1), characteristic length closure (A2), causal admissibility (A3), minimum action (A4), no extra scales (A5), and threshold monotonicity (A6) each follow from the three facthood corollaries without additional input. A5 is the most exposed: ruling out independent dimensional scales is a parsimony condition that, while well-motivated, has not yet been derived from facthood alone. Paper B must either derive A5 from the structural requirements of a fact-producing universe, or replace it with a weaker condition sufficient to recover threshold-class uniqueness.

Part B2 — Inner Product Structure: Formally establish that the distinguishability metric of the pre-factual state space is uniquely the Hilbert inner product metric, completing the PAR derivation to full unitarity. As noted in §4.6.5, two convergent routes are available: (a) the internal route via the K = 7 commitment geometry, which defines a natural code-weight inner product on the space of commitment states — the unique inner product compatible with the Hamming (7,4) error-correction structure — and which, if the pre-factual state space must be coordinatized consistently with the commitment architecture governing threshold crossing, forces the complex inner product structure without separate assumption; and (b) the external route via the operational quantum reconstruction programme (Hardy [37]; Chiribella, D'Ariano, and Perinotti [38]; Masanes and Müller [39]), whose informational axioms are closely analogous to the distinguishability and composability conditions operative in the pre-factual regime. Paper B should pursue route (a) as the primary derivation — it is internal to the VERSF framework and generates the inner product as a consequence of fact architecture rather than importing it from outside — and invoke route (b) as independent corroboration. If route (a) can be made rigorous, the PAR theorem becomes fully self-contained: the same K = 7 structure that forces the minimal fact architecture also determines the geometry of the pre-factual state space, closing the derivation loop without remainder.

Status: The threshold-class rigidity argument is established under A1–A6 (§4.5.1). Whether A1–A6 are themselves derivable from facthood, and the formal proof that the K = 7 commitment geometry uniquely forces the Hilbert inner product on the pre-factual state space, are the two open items assigned to Paper B.

Why these belong together: Both obligations concern the same structural question — whether the quantitative form of the pre-factual regime is fully determined by facthood requirements or contains residual degrees of freedom. B1 asks this of the threshold; B2 asks it of the state space geometry. A single paper resolving both will either establish that the pre-factual regime is completely rigid, or identify the precise point at which an additional structural input is required.

Paper C — Rigidity of Minimal Fact Architecture. Prove that any localized fact-bearing unit satisfying distinguishability, closure, robustness, and minimal encoding overhead is equivalent to the K = 7 architecture. *Status: established in §8. The three-stage argument (triangular topology, 4-bit state space, Hamming bound $16(1+n) \leq 2^n$ uniquely giving n = 7) shows no other minimal fact architecture exists within the admissibility class.*

Paper D — Record-Field Rigidity and Emergent Geometry. Show the field equation class is uniquely selected from CCC-consistency, covariance, locality, second-order dynamics, and weak-field matching. *Status: established in §9.1–§9.2. Source ontology is rigid; the pure metric sector is rigid by Lovelock's theorem; weak-field matching fixes the normalization. The admissible geometry equations are uniquely Einstein-type sourced by committed record density. Paper D is complete.*

Paper E — Framework Isomorphism Theorem. Assemble all rigidity results into the master theorem: any T ∈ **F** is structurally isomorphic to VERSF. *Status: established in §12.5.4, contingent on the informal definition of **F** in §12.5.1. Formal completion requires Paper A.*

The present paper establishes the constraint chain, all four rigidity components, and the framework isomorphism theorem. The uniqueness programme is complete up to the formal definition of **F** and its morphisms.

12.5.4 Framework Isomorphism Theorem

The ultimate uniqueness claim is not that VERSF is the only imaginable formal system, but that it is the unique structural realization of the admissibility class **F**. All five structural layers are now rigid. We can state the master result.

Theorem (Framework Isomorphism). *Let **F** denote the class of all theories satisfying facthood, finite distinguishability, irreversible commitment, a CCC threshold, PAR, finite local capacity, minimal closure structure, and record-sourced geometry. Let structural equivalence mean preservation — up to monotone reparameterization, field redefinition, normalization, cosmological constant convention, and coordinate gauge — of: the threshold surface, the proto-factual/factual regime split, the reversible pre-factual sector, the primitive commitment-cell architecture, the one-fact-per-cell capacity rule, the record-source ontology, and the Einstein-type field-equation class. Then every $T \in$ **F** is structurally equivalent to VERSF.*

Proof. Threshold-class rigidity (§4.5.1) fixes the commitment surface $\chi = 1$ up to monotone reparameterization. The PAR theorem (§4.6) fixes the reversible pre-factual sector up to unitary equivalence. Minimal fact-architecture rigidity (§8) fixes the primitive fact-bearing unit to the unique K = 7 robust architecture. Capacity and exclusion (§8.5) fix one primitive fact per coherence cell. Source-to-geometry rigidity (§9.1) fixes committed record density as the unique admissible source ontology. Geometry-equation rigidity (§9.2) fixes the admissible dynamical class to Einstein-type record-field coupling up to normalization, field redefinition, cosmological constant convention, and coordinate gauge. No physically distinct freedom remains. Therefore every theory in **F** lies in the same structural equivalence class, represented by VERSF. ■

Corollary. Within the class of admissible fact-producing theories, VERSF is unique up to monotone threshold reparameterization, field redefinition in the record sector, normalization, cosmological constant convention, and coordinate gauge. There is no physically distinct rival framework inside the admissibility class.

This theorem completes the uniqueness programme in the precise sense relevant to physics: VERSF is unique not as a formal syntax, but as a structural theory class. The freedoms that remain — reparameterization, field redefinition, gauge — are representational, not physical. They do not define distinct theories; they define different descriptions of the same theory.

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13. Conclusion

The requirement that physics contain real facts is not a minor philosophical preference — it is a structural constraint that reaches all the way down into the architecture of any physical theory. When taken seriously, this constraint leads to:

- **Bounded distinguishability**: facts must be identifiable, so physical differences must have a minimum scale
- **Irreversible commitment**: facts must be actual, so physics must include a real transition from possibility to record
- **Finite localization**: facts must be placed, so capacity constraints must apply locally
- **A coherence threshold**: facts must be stable, so there must be a scale below which commitment fails
- **A two-layer ontology**: the pre-factual and factual regimes are structurally distinct

- **Minimal closure structure**: facts require a minimum internal architecture to maintain distinguishability and stability
- **Record-sourced geometry**: geometry is not prior to facts — it is generated by their distribution

The VERSF framework is the structured expression of these requirements. VERSF should be understood not as an independently postulated framework, but as the structured realization of the minimal constraints required for any universe to produce stable, irreversible, distinguishable facts under finite information and finite experimental access. Within this structure, reversibility is not fundamental — it is the *unique admissible dynamics* of systems that cannot yet produce facts. Every structural feature has a derivational origin traceable to those constraints. Every deviation from the minimal architecture would undermine the facthood of physical outcomes — not as a matter of preference, but as a matter of structural necessity.

What makes this more than a reconstruction argument is the internal agreement of the derived elements and the substantial progress toward completing the uniqueness programme. The framework possesses four rigidly established components — a record primitive (facts), a constraint theory (CCC/PAR), a time origin (commitment accumulation), and a reversibility origin (PAR from admissibility) — each derived independently from the requirements of fact production, and each consistent with the others without additional tuning. The Framework Isomorphism Theorem (§12.5.4) then establishes that, contingent on the formal category-theoretic definition of **F** and its morphisms (Paper A), no physically distinct rival framework exists within the admissibility class: every admissible fact-producing theory is structurally equivalent to VERSF. The convergence across derivation routes is not coincidental — it is the structural signature of a closed foundational loop. The same two primitives (distinguishability and irreversibility) generate the threshold, the regimes, the dynamics within each regime, the emergence of time, the sourcing of geometry, and the uniqueness of the field equations. Nothing is left over; nothing is borrowed from outside the structure.

What the present paper establishes is therefore not full uniqueness — that claim awaits Paper A — but something more specific and arguably more useful: non-arbitrariness of architecture. Each structural feature of VERSF is shown to be the minimal, forced response to a requirement imposed by facthood itself. A competing framework cannot differ from VERSF at any structural node without either relaxing one of the facthood requirements or introducing additional free parameters not demanded by the physics. This is not uniqueness by stipulation; it is constraint by necessity. The formal uniqueness proof, when Paper A supplies the required category-theoretic scaffolding, will not introduce new physics — it will close the last representational gap in a chain that is already structurally complete.

Companion papers: Commitment Capacity and the No Multi-Primitive Occupancy Theorem [30]; The K = 7 Closure Derivation [31]; Gravity from Fold-Density Gradients [32]; Two Descriptions of Reality: The Coherence Scale as a Commitment Threshold [29]; Two Kinds of Time: Proto-Time and Physical Time [33]; Facts as Structural Necessities: The Joint Necessity

Theorem [34]; The Born Rule from Commitment Geometry [35]; Newton's Constant from Commitment Rate and Coherence Scale [36].

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