Frozen Reality and the Emergence of Time

A VERSF Perspective on Sequential Updating, Operational Depth, and the Illusion of Temporal Flow

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Abstract for the General Reader

Imagine pressing pause on the universe — every motion, every interaction, every signal between particles, every moment of memory or measurement, all halted together. Would the world still be three-dimensional?

The intuitive answer is yes. A frozen apple still has length, width, and depth. This paper argues that the intuitive answer mistakes a feature of our *descriptions* for a feature of the *world*. What makes something three-dimensional in any physically meaningful sense is not that we can label it with three coordinates. It is that the world can act along three independent directions — distinguishing, comparing, persisting. Strip away the activity and what remains is a mathematical sketch, not a physical thing.

A sharper version of this concerns depth specifically. Surface information about an object is given all-at-once — no traversal required. But the interior of any region is reachable only through sequential probing: a signal must propagate inward, a comparison must traverse from layer to layer, a measurement must resolve one depth after another. Take away the dynamics that make such probing possible and the interior remains mathematically present but operationally unreachable. The same structural pattern — 2D input from which a 3D percept is *constructed* — turns out to recur in everyday perception. You are walking down a street; time freezes. What you can see is a frozen 2D image — the slice of light reaching your retinas at the instant of freezing. The brain ordinarily turns such 2D input into a 3D percept through binocular disparity, depth cues within the frame, and integration with subsequent updates as you move. With time frozen, the construction process is suspended; you are left with the 2D input. The 3D information about the depth of the road or what is around the corner is *there* in the coordinate sense, but the construction that turns 2D retinal data into a 3D world-percept has stopped. Allow time to resume and the depth returns: not because anything new was created, but because the construction process is once again happening. The vignette is not itself the metaphysical claim — that claim is about substrate-level commitment, not perception — but it makes vivid the structural pattern that the framework proposes also holds at the substrate level: depth is not a static property an object simply *has*; it is something continuously made accessible by ongoing activity, with the third dimension reconstructed from intrinsically 2D content.

The consequence for time is unfamiliar. Most pictures of physics treat time as a background dimension the universe moves through, like a river carrying objects downstream — and the more

sophisticated "block universe" picture says all moments equally exist in a static four-dimensional totality. The VERSF framework proposes something different: there is no river, and no totality. To be *physically* real rather than merely a useful mathematical picture, the block universe would need to be instantiated somehow — and instantiating all moments at once would require simultaneous access to the entire four-dimensional structure, the very thing nothing in the universe ever has. Every interaction, every measurement, every causal process — observed or unobserved — happens at the currently committed moment; the past survives only as present records (memories, fossils, photographs), the future only as unrealised potential. What we experience as the flow of time is the ordered sequence of small, irreversible events by which the universe continuously commits itself into being. Geometry is real and stable, but it is continuously *reconstructed*, not statically *contained*.

Behind both halves of the argument lies a single architectural fact: physical reality, at every level, is *interface-like*. What can be simultaneously committed at any moment is boundary-level content; the full three-dimensional depth of a region is reconstructed across many committed moments linked by causal continuity. The pattern shows up at every scale we can examine — in a vibrating metal plate where elaborate patterns emerge on a 2D surface from sustained activity (a cymatic plate), in a screen building depth from pixel updates, in the way the three-dimensional world we live in is held together by countless ongoing physical processes. VERSF's claim is that reality at its most fundamental level is the most basic instance of this universal pattern: *reality is in the chain, not in the slice*. The paper makes this precise, formalises the conditions for operational three-dimensionality, and positions the resulting picture against the standard alternatives — the static "block universe", Barbour's timeless physics, and the Page–Wootters relational reading. Its central thesis is that the deepest fact about the world is not that it *is* but that it *commits* — and that time, on this view, is not something happening in space but what continuously actualises spatial depth itself.

Contents

Abstract

This paper develops a precise sense in which the universe's three-dimensional structure is real, while the experienced flow of time is emergent. We pose a single operational question:

If reality were completely frozen — every interaction, propagation, comparison, and record-formation halted — would anything still meaningfully possess three-dimensional physical properties?

The answer, within VERSF, is **no, not operationally**. A frozen universe may retain a mathematical configuration, but the operational content of three-dimensional physicality — distinguishability, comparison, persistence, and causal coupling — collapses without ordered commitment updates.

We develop this conclusion along two complementary lines. The first is an *accessibility argument* with spatial and temporal halves. Spatially, boundary information is given by simultaneous specification but bulk depth is physically accessible only through sequential causal resolution; freezing the substrate leaves a mathematically three-dimensional object with only two-dimensions-worth of accessible information — a convergence with holographic reasoning that suggests the depth-dynamics relation is structural rather than theory-specific. Temporally, along any commitment chain through Λ, physical accessibility at any chain-position is confined

to the locally committed slice plus its records and adjacent potentialities; no physical system in the universe, observed or unobserved, ever instantiates the four-dimensional totality the block view posits. The second is a *formal argument*: the **operational dimension** of an object is defined in terms of the rank of distinguishable-fact variation under an ordered update parameter Λ, and this rank is undefined when Λ is removed. Λ itself is pinned down as the partial order generated by causal dependence among commitments on the interface — not a flowing parameter but the order-theoretic structure from which linear, proper-time-like chains emerge only by coarse-graining.

From the temporal half follows a critique of the block universe. The block — claiming all events equally exist as a 4D physical totality — would require an accessibility structure hosting all temporal layers as physically simultaneous; none exists in the universe. The block defender faces a trilemma (§13.2): concede the block as mathematical representation rather than state of affairs; posit an unexplained 4D meta-interface; or invoke atemporal ordering that reintroduces the very temporal structure the view sought to eliminate. None preserves the original reading.

Both halves of the accessibility argument, and the trilemma that follows, share a single underlying principle:

Spatial dimensionality is not fully encoded within isolated instantaneous states, but emerges from coherent causal continuity across informational updates.

A single momentary slice contains state information but no evolution, propagation, persistence, motion, or realised three-dimensional depth — all of which are relations across slices rather than features of any single one. What does the constructive work is not bare temporal succession but the *causal* coherence of the chain: successive slices linked by relations of inheritance, with comparison relations preserved as records and structural propagation coherent across updates. Reality is therefore not a static geometry but a causally sustained chain of fact-commitment updates, and the three-dimensionality we encounter is what such a chain *does* as it sustains itself.

Underlying this principle is a structural reason why the substrate must take interface form at every position in Λ. Bulk-level distinctions cannot be simultaneously committed, because their constitution requires the chain that simultaneous commitment lacks — a circularity the substrate cannot resolve, given the §9.1 operational-ontological identification and the substrate-first dynamicism the operational arguments motivate. What can be simultaneously committed is boundary-level content; bulk depth must be reconstructed across causally linked updates. *The substrate behaves interface-like because simultaneous physical accessibility structurally privileges boundary commitments over fully realised bulk states; bulk dimensionality is reconstructed only through coherent causal continuity across successive interface updates.* The holographic resonance flagged earlier is *consonant* with this structural argument, though the §11 claim is not strong enough to derive the specific encodings of AdS/CFT or related programmes; the convergence is informative without being entailment.

The conclusion is not that 3D space is illusory. It is that **3D physicality requires ordered fact-updates**, and what is illusory is the assumption that those updates must be sequenced by a fundamental flowing time dimension. In VERSF, the update ordering is supplied by irreversible

commitment events on the active interface; the experience of temporal flow emerges from the monotonic growth of the record field $\rho(x, \lambda)$, not from traversal of a pre-existing temporal axis. Spatial depth, on this account, is not something an object merely *has* but something continuously *actualised* by substrate activity — each commitment along a chain through Λ resolves an additional layer of bulk distinction. This relocates becoming from a background dimension into the substrate's own operational activity, distinguishing the VERSF picture sharply from both the static block universe and the strictly timeless proposals of Barbour and Page–Wootters. Mathematical spacetime may be four-dimensional; operational reality is always interface-like.

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1. Introduction

Modern physics treats spacetime as the arena in which physical events occur. In Newtonian mechanics, relativity, and quantum field theory, time enters as a parameter along which systems evolve. The mathematical formalism is exquisitely successful, but it leaves a conceptual residue unaddressed:

Why does reality appear to unfold sequentially rather than exist as a static four-dimensional structure?

Equations describe change; they do not explain why change is *experienced* as flow. Standard responses split into two camps. The **block universe** declares the flow an illusion of consciousness while keeping a static four-dimensional manifold. The **timeless** proposals of Barbour and the Page–Wootters mechanism go further, eliminating fundamental time altogether and recovering apparent temporal evolution from relational or entanglement-based structure.

VERSF takes a third route. Earlier papers in the programme established that:

- irreversible commitment is fundamental;
- records accumulate monotonically along a partial ordering of commitment events;
- the physically active substrate is a lower-dimensional commitment interface;
- and operational time is identified with record growth, not with a pre-existing dimension.

The present paper sharpens a specific implication of that framework:

Three-dimensional structure persists as a coarse-grained reconstruction over the record field, but its operational content requires ordered fact-updates. The familiar sensation of flowing time emerges from the ordering of those updates, not from a flowing background dimension.

This is a subtler claim than either "time is real" or "time is illusory". It separates three things normally conflated: **static mathematical structure**, **committed geometric structure**, and **operationally experienced reality**.

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2. Claim and Scope

To avoid the standard ambiguities in this area we state our claims explicitly.

Claim 1 (Geometry persists). Three-dimensional spatial structure is real and persistent. Folds, closure relations, and the record field $\rho(x, \lambda)$ carry coarse-grained geometric content that survives across commitment updates.

Claim 2 (Operational physicality requires updates). The operational content of three-dimensional physicality — distinguishable extension, causal coupling between regions, persistence-through-comparison — requires an ordered update parameter λ. Without λ, the dimensionality of an object is operationally undefined.

Claim 3 (Flow is emergent, becoming is not). The *experience* of temporal flow is emergent from the ordering of commitment events. But becoming itself — the irreversible accumulation of records — is fundamental. VERSF therefore rejects both the static block universe (which denies becoming) and naïve presentism (which reifies a flowing now).

Scope. We are not arguing that observers are necessary, that consciousness creates time, or that the universe is mind-dependent. The argument is fully objective: commitment events occur whether or not anyone observes them, and record growth is a substrate property, not an epistemic one.

A note on argumentative structure. The three claims above, together with the metaphysical identification in §9.1 and the structural derivation in §11, form a *mutually supporting package* rather than a strictly linear chain. The methodological note at the end of §11.5 makes the package character explicit and addresses readers who would press the argument at the level of individual moves rather than the package as a whole.

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3. The Frozen-Reality Thought Experiment

Imagine freezing reality entirely. Not slowing physical processes; not freezing perception while leaving physics active; but freezing:

- all motion,
- all field propagation,
- all interactions,
- all information transfer,
- all record formation,
- and all commitment updates.

In such a state:

- no photons propagate,
- no clocks tick,
- no comparisons occur,
- no measurements happen,
- no new distinctions form,
- and no records accumulate.

A mathematical arrangement of structure may still exist. But several things normally taken for granted vanish operationally:

- *distance cannot be traversed*, because traversal requires an ordered sequence of position-updates;
- *persistence cannot be confirmed*, because confirmation is a comparison across updates;
- *causal order cannot evolve*, because evolution is precisely what has been removed;
- *dimensionality cannot be tested*, because testing requires probing along independent directions, which requires comparison across updates.

The world becomes **structurally present but operationally inert**. This is the first piece of evidence that geometry alone is insufficient to generate an experienced physical world.

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4. Three Levels: Structure, Commitment, Experience

The frozen-reality scenario forces a distinction that ordinary physics elides. We separate three levels:

Level 1 — Mathematical configuration. A set of points, relations, and labels. This is the level of pure structure: a configuration in some abstract space. It is consistent, possibly elegant, but operationally inert. A frozen universe possesses only this level.

Level 2 — Committed structure. A configuration whose distinctions have been *irreversibly committed* by the substrate. Records exist; the field $\rho(x, \lambda)$ has some non-trivial content. But there is no further updating. Counterfactually, this is a "snapshot" of a real universe.

Level 3 — Operational reality. Committed structure plus ongoing commitment updates. New folds form; the record field grows; comparisons occur; persistence is actively confirmed.

The frozen-reality scenario removes Level 3 while leaving Level 1 in place. The question is whether what remains is a physical world or a mathematical fossil. Our answer: it is the latter. **Level 1 is necessary but not sufficient for physical reality.** Level 3 supplies the operational content that makes spatial extension, causal coupling, and persistence physically meaningful.

This is not idealism. The substrate is fully objective. But it is *active*: physical reality is something the substrate continuously *does*, not something it statically *is*.

5. The Flip-Book Analogy

A useful analogy is a flip-book. Each page is static; no page contains motion. Yet when pages are updated in rapid sequence, motion appears, persistence appears, and a flowing visual world emerges. The motion is **not contained inside any single page**. It emerges from the ordered progression between pages.

VERSF proposes that physical reality behaves similarly, with two important refinements:

1. The "pages" are not separately existing snapshots. There is no pile of pre-existing slices waiting to be flipped through. Commitment events *produce* the structure they record.
2. The progression is not externally driven. There is no hand flipping the book. The substrate updates itself; the ordering is intrinsic to commitment.

The analogy is therefore loose but suggestive. It captures the key point that flow can be a property of ordered updates rather than of any individual configuration.

A sharper formulation: rather than *objects moving through a pre-existing flowing time*, reality consists of *persistent structure undergoing sequential reconstruction along an intrinsic ordering of commitment events*.

A caveat that §12 will sharpen. The flip-book illustrates emergent flow from ordered updates, but it does so by means of an external lawgiver — the illustrator — whose intentions supply the coherence between pages. The pages themselves have no causal dependence on each other; the dependence lives elsewhere. §12 will argue that VERSF requires something stronger: causal continuity in which successive states inherit structure from their predecessors via the substrate's own dynamics, with no external coherence-supplier. The flip-book's bare succession is illustratively useful but insufficient as a model of substrate activity; §12 supplies the upgrade.

6. Sequential Commitment and Operational Time

Within VERSF, a fold is an irreversible committed distinction. Each fold contributes to the accumulated record field

$$\rho(x, \lambda) = \Sigma_l \chi_l(\lambda)\, \delta^3(x - x_l),$$

where $\chi_l(\lambda)$ is the commitment-weight of fold ℓ and λ indexes the ordering of commitment events. Earlier VERSF papers established the monotonicity condition

$$\partial\rho/\partial\lambda \geq 0,$$

i.e. records grow monotonically along the commitment ordering. This monotonicity is the substrate's irreversibility, expressed at the record level.

Operational time emerges from this structure in three steps:

1. **Ordering**: commitment events admit a partial order via their record-incidence relations.
2. **Accumulation**: records grow monotonically along this order.
3. **Distinguishability**: at any λ, the committed past is distinguishable from the uncommitted future precisely because ρ carries the accumulated structure of one and not the other.

The arrow of time is therefore not imposed externally; it is the asymmetry between "what ρ has recorded" and "what ρ has not yet recorded". Without record accumulation, no operational past/future distinction exists, and temporal ordering loses physical content.

We arrive at the VERSF identification:

Operational time = ordering of commitment updates on the active interface.

This is not a redefinition of time as a mere label. It is the claim that what we have always called *time* is operationally indistinguishable from — and theoretically reducible to — the commitment ordering, with no remainder.

6.1 What kind of object is Λ?

Λ has been doing significant work in the argument, so its status needs to be pinned down. Four nearby readings are tempting, and the paper's force depends on choosing among them rather than leaving them flexible:

1. **Update count** — Λ as the cardinality of committed events.
2. **Causal depth** — Λ as the longest chain of commitments preceding a given fold.
3. **Proto-time** — Λ as a not-yet-time precursor, suggestive but unstructured.
4. **Pure ordering** — Λ as the partial order on commitment events, and nothing more.

VERSF adopts reading 4. The other three are recovered as coarse-grained features of it.

Λ is the partial order generated by causal dependence among commitments on the interface.

Its elements are commitment events; its ordering relation $a \prec b$ is the substrate-level dependence "the record content of a is necessary for the commitment of b." Λ is not a number, not a count, not a dimension, and not a parameter. There is no global "value of Λ" at a point on the interface; there is only a position within the partial order. The notation λ used earlier — and in the record field $\rho(x, \lambda)$ — should be read as standing for such a position, not as a real-valued coordinate.

The other readings then re-enter as derived quantities:

- **Update count** = cardinality of an order-ideal (a down-closed subset of Λ). Well-defined for any chosen ideal but not a property of Λ itself.
- **Causal depth** = length of the longest chain terminating at a given fold. Meaningful for individual events but undefined globally.
- **Linear monotonic time** emerges by selecting a coarse-grained chain through Λ. Different choices of chain correspond to different foliations.

Three consequences follow that no other reading delivers cleanly:

1. **Locality of time.** Different regions of the interface support different commitment chains; there is no substrate-level global "now". This is the foundational origin of what general relativity expresses as the absence of preferred simultaneity.
2. **Frame-dependence of duration.** Duration along a worldline is the count of commitments on the chain through it, which depends on the foliation. This is the substrate-level origin of relativistic time dilation; it is not an additional postulate but a coarse-graining fact.
3. **Monotonicity without backward time.** A partial order is antisymmetric by definition, so no consistent coarse-graining can produce a reversed chain. Backward time travel is ruled out at the level of Λ's order-theoretic structure, not by a separate physical principle.

"Flow" of time, in this picture, is the experienced traversal of a coarse-grained chain through Λ. The flow is real but does not correspond to any feature of Λ itself; Λ is structural, not directional. Direction enters only through record growth, which selects one ordering of any given chain as the operative one.

This positioning is precise:

- **Against substantivalism about time:** Λ is not a dimension or container.
- **Against Barbour-style timelessness:** Λ is not eliminated; it is the real and ineliminable source of operational ordering.
- **Against discrete-tick atomism:** Λ is not made of ticks at a fixed grain; the grain is set by coarse-graining and is not unique.
- **Against the substrate-as-process readings of Whitehead and Bergson:** Λ is structural rather than experiential, and its ordering is determined by causal dependence at the substrate level, not by phenomenal succession.

Λ is what the substrate's ordering *is*. Time is what one coarse-graining of that ordering *looks like from inside*.

Quantum non-locality and antichains. Λ's partial-order structure has implications for how quantum correlations across spacelike-separated regions should be understood. Commitments at spacelike-separated regions are *antichain* elements of Λ: they are unordered with respect to each other, neither being a causal ancestor of the other. The structure accommodates two facts simultaneously. First, no causal influence flows between spacelike-separated commitments — antichain elements cannot pass record content to one another within Λ's ordering, which is the substrate-level statement of no-signalling. Second, correlations between them are not ruled out:

antichain pairs may share common causal ancestors lower in Λ whose joint record content underwrites observed correlations. Bell-type quantum correlations, on this reading, are correlations across antichain elements of Λ with shared ancestors, not causal influences between spacelike-separated commitments. The standard treatment of quantum non-locality as "no signalling but real correlation" is the operational expression of this antichain structure. A fuller development belongs to the VERSF quantum foundations papers; the partial-order treatment of Λ provides the structural setting in which that development sits.

A note on Λ's own ontological status. A careful reader will press whether Λ-taken-as-a-totality is itself subject to the kind of instantiation question §13.2 raises against the block manifold. A block defender may say: "You treat Λ as the relational shape of the commitments. I treat the manifold as the relational shape of the events. Why are these treatments asymmetric?"

The disanalogy is not between two relational shapes but between two attitudes to what the relata are. Λ's elements — the commitments — are themselves *operationally* constituted: each commitment is substrate activity, and the operational arguments of §§8, 10, 11 turn on what the substrate can simultaneously commit. The "relational shape" Λ inherits from operationally-constituted relata. The block defender's manifold, by contrast, would inherit its relational-shape status from operationally-inert relata: the events the manifold relates are taken to exist as a totality with simultaneous physical standing, which is precisely the totality-claim §13.2 contests. Λ is a relational shape of operationally active commitments; the block manifold would be a relational shape of operationally inert posited events. The first inherits operational content from its relata; the second has nothing to inherit. Λ-as-totality is not separately instantiated because there is nothing separate to instantiate: the elements *are* the structure, the elements are themselves operationally accessible, and the structure *is* the elements' relational shape.

This connects naturally to §6.2's distinction-ontology — folds are not objects in Λ, and Λ is not a container of folds; both are aspects of the substrate's recurrent asymmetry process viewed through different lenses.

6.2 What kind of object is a fold?

A parallel question to §6.1 deserves the same care. We have spoken of "folds" as if they were countable objects — irreversible committed distinctions that the substrate accumulates one by one, and which collectively populate the record field ρ. This usage is technically convenient but ontologically misleading, and the misreading must be dispelled before the later arguments rest on it.

A fold is not an independently existing object. It is a recurring manifestation of the same fundamental asymmetry process within the substrate.

There is, in this sense, one fold-mechanism, capable of repeated self-instantiation, rather than many separate fold-objects assembled side by side. Plurality of folds is not the existence of many separate entities; it is the recurrence of a singular distinguishing process across distinguishable contexts.

This shift matters. A reader inheriting object-ontology intuitions from classical physics or naive set theory will read "folds plural" as "many things of a certain kind," each a separate entity with its own existence, and will ask how these separate entities relate to one another. On the VERSF reading, the question is misframed. The relevant question is not how separate fold-objects coordinate but how the singular asymmetry process individuates its recurrent applications.

The void, the substrate, and the 2D interface. The void and the substrate in VERSF are the same single fundamental reality. There are not two distinct levels of reality here: "void" and "substrate" name one thing under different descriptions. The void is the substrate at the limit of no committed distinction — its symmetric, undifferentiated condition. When commitments occur, they occur at the substrate's *interface*: a structural feature of the void/substrate, not a separate entity. The interface is to the void what a surface is to a bulk — structurally distinct, ontologically inseparable. We adopt the term "interface" here for the substrate's active aspect; the structural argument that this active aspect must be 2D-shaped — that simultaneous commitment at any Λ-position can only occur boundary-level rather than bulk-level — is deferred to §11. With that deferral noted, the broader claim §11 will deliver is that all *simultaneously* committed content at any Λ-position arises at this interface by necessity given substrate-first dynamicism: simultaneous commitment can only occur interface-shaped.

A fold is the minimal asymmetry that breaks the void's symmetry — the substrate's smallest possible commitment of "this rather than that," occurring at the interface. Void and fold are not on the same ontological level. The void is the symmetric background condition; the fold is the operation by which distinction enters. A single fold has no plurality and no "neighbouring folds" to relate to. But the asymmetry process is recurrent: once one distinction has been committed, the substrate's state is altered, and further distinctions can be committed in relation to it at the interface. What we call "many folds" is the recursive application of the same singular asymmetry process to a substrate increasingly differentiated by its prior commitments.

Identity is relational, not absolute. A consequence falls out immediately. If folds are repeated self-instantiations of one process, two folds are not "different things" in any classical sense. They are the same act of distinction, recurring in distinguishable contexts. Their identity is *positional* rather than *intrinsic* — what distinguishes one fold from another is its place in the substrate's causal structure, its relational context, its update history, and its coherence relations with other folds. This is precisely the structure modern physics already accepts for its most fundamental entities. Electrons are identical: there is no fact about *which* electron we have, only about how many electrons in what state. Quantum fields are fundamentally unified: what we call "particles" are excitations of a single underlying field, not independent things added to a pre-existing inventory. The VERSF fold concept moves naturally toward the same structure: folds are not objects within a substrate but distinguishable commitments of a substrate, repeatable but not pluralised in the classical sense.

Space emerges from adjacency, not the reverse. This reading also clarifies how spatial structure arises in VERSF. If folds were independent objects sitting in a pre-existing spatial arena, "space" would be the container and "folds" would be its contents. But folds are not objects, and there is no pre-existing arena. What there is, instead, is the relational structure that recurring asymmetry events produce: adjacency relations between folds, coherence relations

across commitment chains, stable patterns of inheritance. Space is what such relational structure *looks like* when it is coarse-grained. Stable adjacency generates effective metric geometry; coherent propagation generates effective directionality; persistent record-relations generate effective extension. None of this requires a prior spatial arena. The metric structure of physical space is what the substrate's recurring asymmetry process produces, not something the substrate is set in. This is much stronger conceptually than imagining tiny geometric tiles floating in pre-space.

Difference is fundamental; things are emergent. The metaphysical move underlying all this can now be stated explicitly:

Difference is fundamental, while separate "things" are emergent.

The void is not a region containing nothing; it is undifferentiated potential. A fold is not a thing; it is an act of distinction. Reality is not a collection of objects; it is the recursively stabilised network of distinctions the substrate has committed. The shift from object-ontology to distinction-ontology is the philosophical pivot on which the entire VERSF framework turns, and it explains why the language of "folds" sometimes strains classical readings — the readings were assuming an ontology VERSF does not share.

This positioning is precise:

- **Against atomism:** the substrate does not consist of irreducible particles or fold-objects.
- **Against substantivalism about space:** there is no spatial container in which substrate activity occurs.
- **Against pluralism about events:** events are recurrent instantiations of a singular act, not independent entities.
- **For relational identity:** what makes one fold distinguishable from another is its position within the substrate's structure of commitments, not its intrinsic nature.

The fold is what the substrate *does*, not what the substrate *contains*. Folds plural are the substrate's repeated act of distinguishing, individuated by the relational context each instantiation creates and inherits. With this in place, the use of "folds" in subsequent sections — and the chain-of-slices framing in §12 — should be read in this distinction-ontological key, not in the object-ontological key the language sometimes superficially invites.

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7. Why Three-Dimensional Structure Persists

The present account does not deny that the world is three-dimensional. Stable spatial structure is *reconstructed continuously* from persistent record relationships. In VERSF:

- folds persist across updates,
- closure structures stabilise,
- records accumulate coherently,

- and geometry emerges from coarse-grained reconstruction over ρ.

A chair remains a chair across many commitment updates because its underlying record structure is closure-stable; the spatial pattern persists across the ordering rather than being re-imposed each tick.

The point is therefore not that geometry is unreal, nor that persistence is illusory. It is that **both geometry and persistence are operational properties of the updating substrate**, not properties of a static container into which substrate activity is poured.

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8. The Accessibility of Depth: Boundary, Bulk, and Sequential Resolution

The argument so far establishes that operational three-dimensionality requires ordered fact-updates. This section sharpens the *reason* by introducing a distinction the standard framing obscures: in a frozen scenario, not all information is lost equally. Boundary information remains simultaneously specified; bulk information becomes physically inaccessible. The mode of access differs by dimension.

This is the deepest version of the frozen-reality argument. It shifts the question from *does geometry exist?* to *what information is physically accessible?* — and the answer reveals that depth and dynamics are co-constituted in a way the standard picture conceals.

A vivid first-person illustration makes the access-asymmetry concrete — though with a level-flag worth raising before the example begins. The thought experiment that follows illustrates a *structural pattern* — 2D input giving rise to a constructed 3D percept — that recurs at multiple levels of physical organisation. The vignette is not direct evidence for VERSF's ontological thesis; the ontological thesis is about substrate-level commitment, not about visual perception. What the vignette does is exhibit the same chain-not-slice structure at the level of everyday perception, where the reader can verify it against personal experience. The §15.3 disclaimer that VERSF is not idealism applies here too: the pattern is structural, not perceptual.

With that level-flag in place: you are walking down a street. Time freezes. What you can see is now a frozen 2D image — the slice of light reaching your retinas at the instant of freezing. The brain ordinarily constructs the 3D world from such 2D input through binocular disparity, perspective and depth cues within each retinal frame, and integration with subsequent updates as you move. With time frozen, the construction process is suspended and you are left with the 2D input the brain was working from. The 3D information about the depth of the road, the structure of the buildings, what is around the corner is *there* in the coordinate sense — but the construction that turns 2D retinal data into a 3D world-percept has stopped. Allow time to resume and the depth returns: not because anything new was created, but because the construction process is once again happening. Depth perception, ordinarily so immediate that it feels like a static property of the scene, is in fact something the brain is continuously *building* from intrinsically

2D input. The structural pattern recurs at the substrate level on the VERSF picture: 2D content committed at each Λ-position; 3D bulk reconstructed across the chain of commitments. The rest of this section develops the substrate-level point rigorously, but the pedestrian's frozen moment is the picture to keep in mind for the structural shape of the argument.

8.1 Simultaneous specification vs sequential resolution

Consider any region of space and the interface enclosing it. Information defined on the boundary is, by construction, accessible without traversal. A surface fact is given all-at-once; reading it requires no journey across other surface facts. Information defined in the bulk — interior layers, deeper structure, the inside of a volume — is accessible only by *sequential causal resolution*. A signal must propagate inward; a comparison must traverse from one layer to the next; a probe must reach the interior across an ordered chain of intervening points.

This asymmetry is not a feature of any particular physical theory. It is structural. Probing the interior of a region requires:

1. an ordering of layers from boundary inward;
2. a signal or process that traverses this ordering;
3. the capacity for that signal to register distinct facts at each depth.

All three require sequential access. Boundary information requires only simultaneous specification. The two modes of information are physically distinct, and they fail differently under loss of substrate updates.

8.2 The frozen cube

Apply this to a frozen cube. Mathematically, the cube has interior coordinates and a well-defined volume. Operationally, in the frozen state:

- no signal can propagate through it;
- no observer or interaction can probe its interior;
- no causal chain can resolve one depth layer from another.

Everything that remains operationally accessible is whatever is encoded *at the boundary*. The interior is not gone in the coordinate sense; it is *causally inert*. Its depth is unreachable from any process the substrate could perform.

This is not the claim that the cube becomes two-dimensional. The cube's mathematical structure remains three-dimensional in sense (1) of §9.1 below. The claim is that **the operational content of three-dimensionality requires sequential resolution**, and freezing the substrate eliminates the resolution while leaving the coordinate description intact. The result is a mathematically three-dimensional object with two-dimensions-worth of accessible information.

8.3 The screen analogy

A familiar contemporary phenomenon illustrates the structure of the claim. A television or computer screen is, at the substrate level, a two-dimensional surface — a grid of pixels arrayed on a plane. Yet it delivers a compelling three-dimensional experience. We see objects approach and recede, walk around scenes, perceive depth, distinguish foreground from background, follow figures through space. None of this depth exists *in* the screen; the screen has none. The depth experience is *constructed* through sequential updates of a fundamentally two-dimensional active substrate.

What does the construction require?

- A two-dimensional surface that can host distinguishable facts (pixel values).
- A sequential update process (frame refresh) that changes those facts in coherent ways.
- An interpretive coarse-graining (in the standard case, a viewer) that integrates the updates into a depth percept.

Take away the sequential updates and the screen reverts to a frozen two-dimensional pattern. The depth experience collapses immediately — not because the screen has lost a dimension, but because the construction process that produced the depth has stopped. The 2D substrate is still present; the 3D experience is not. The same screen, in active and frozen states, exhibits exactly the gap between *potential* and *realised* depth that the cube example pointed to in §8.2.

VERSF proposes that physical reality is structurally analogous, with two important differences:

1. The substrate is not a screen viewed externally. It is the commitment interface, and there is no external viewer. The "depth experience" in the VERSF case is whatever it is for a record-rich coarse-graining of substrate activity to be present to itself.
2. The construction is not the rendering of a pre-existing 3D scene. There is no scene behind the screen. The substrate's commitment activity *produces* the bulk distinctions; it does not transmit a depth that exists independently elsewhere.

With those caveats noted, the structural claim is clean: a lower-dimensional active substrate, sequentially updated, produces an effectively higher-dimensional experienced world. This is what the frozen-reality conclusion is pointing at. The world is not a static three-dimensional thing sitting in a four-dimensional container. It is what a continuously-updating substrate looks like when its accumulated activity is coarse-grained from the inside.

(A note on dimensionality: the screen's specific 2D-ness is convenient for illustration, but the structural argument that the substrate must be 2D — not some other lower dimension — is the subject of §11. The §8 sections use the 2D framing as the operating assumption; §11 justifies it.)

The analogy is also useful for what it makes obvious: that the construction is *real* even though the depth is *constructed*. A 3D movie scene is genuinely experienced; it has effects, it can be measured, it can be interacted with. Calling it "constructed" is not a way of saying it is less real than something else. It is a way of saying that what we are calling its three-dimensionality is the output of a process, not the inert property of a thing.

A third disanalogy is worth flagging explicitly. A screen's updates are driven by an external signal source — a GPU, a broadcast feed, a stream of input — and the depth experienced is the construction of *pre-computed* content into perceptual form. There is therefore an *elsewhere* (the GPU's computation, the recorded scene) where the depth being rendered already exists in some higher-dimensional form. The substrate has no analogue of this elsewhere; there is no "off-screen" computation in which the depth pre-exists. The §8.4 paper pad analogy is more accurate on this point: the depth there is constituted entirely by the relation between pages, with no pre-existing higher-dimensional content the pages are tracking. Where the two analogies pull in different directions, the paper pad gives the more faithful picture of what VERSF requires.

8.4 The paper pad analogy

A second analogy sharpens what the screen example leaves slightly ambiguous. Consider a pad of paper with a cube drawn on the first page. Only by turning the page — accessing a *second* two-dimensional surface — can you make progress through the geometry of the cube. A cross-section here, a different perspective there, another slice deeper still. The depth of the cube is not contained in any single page. It is *constituted by the ordered relation* between pages.

This is the structure of how science actually accesses bulk geometry in a wide range of contexts. Computed tomography stacks 2D slices to reconstruct 3D anatomy. Architectural drawings build a building from successive plan and section views. MRI and ultrasound render depth from sequences of essentially planar measurements. Stereographic photography reconstructs depth from a pair of 2D images taken from different positions. None of these techniques *encodes* the depth in any individual image. Each image is intrinsically 2D. The depth lives in the *sequence*.

The point this sharpens is the following. The screen analogy might invite the misreading that the depth is somehow *encoded* in the screen and merely *decoded* by the updates. The paper pad blocks that misreading. There is no temptation to say the depth is "stored" on any page; each page is plainly just a page. The depth is not encoded anywhere singular at all. It is the relation between successive 2D specifications, and that relation only exists when there is more than one page to relate. Take away the additional pages and you have a drawing, not a cube.

The paper pad does not, however, fully escape the screen's deeper problem. The illustrator drew the cube knowing what the cube was; the depth-information was present in their mind before any page was drawn, and the pages distribute *pre-existing* depth content rather than constituting depth *de novo*. Like the screen with its GPU, the paper pad has an "off-page" source of the depth content — the illustrator's intention — that the VERSF substrate has no analogue of. The paper pad is therefore an improvement on the screen with respect to the encoding/decoding misreading, but it is still a partial analogy: useful for showing that depth lives in inter-page relations rather than within pages, but not yet showing that those relations can *constitute* depth without a pre-existing source. The cymatic plate of §11.4 is the analogy that addresses this further: there, the pattern emerges from the relation between plate geometry, driving frequency, and grain dynamics, with no pre-existing "design file" specifying the pattern. The paper pad shows that the relational structure exists; cymatics shows that such a relational structure can be *dynamically sustained without a pre-stored source* — the pattern is not retrieved from an off-page design file but constituted by the ongoing relation between plate, driving signal, and grain dynamics. This is

the sense of "productive" the §8.4 argument needs: *no elsewhere where the depth pre-exists*. A stronger sense of productivity — that later substrate commitments are not derivable from prior conditions at all — is a separate VERSF claim that the cymatic analogy does not illustrate, and §11.4 will be explicit about that limit. For §8.4's purposes, the no-off-page-source sense is what matters; for §11.4's purposes, the modal-determinism limit is what matters; the two uses are consistent.

Map this back to VERSF. A single moment on the commitment interface contains whatever boundary information has simultaneously committed at that moment — a single page. To access bulk depth, to resolve the interior of any region, requires further commitment events ordered along Λ — further pages. The bulk is not stored anywhere at any single position in Λ. It is constituted by the ordered relation between successive commitment events. Stop the sequence and you have one page; you do not have a cube.

This brings the accessibility argument to its sharpest form:

Spatial depth is not a property a moment has. It is a relational structure across moments.

The substrate's continuous addition of pages is what makes the cube a cube. The screen analogy showed that a lower-dimensional active substrate produces a higher-dimensional experience; the paper pad analogy shows where the extra dimension *lives* — not in the substrate, not in any single update, but in the ordered relation between updates. Depth is *between*, not *in*.

8.5 The holographic resonance

This pattern echoes — without committing to — the structure of holographic reasoning in contemporary theoretical physics. In holography, the information content of a bulk region is encoded on its bounding surface; the dimensions of "where information lives" and "where it geometrically appears" come apart. The VERSF accessibility argument arrives at a related place from the opposite direction: when sequential resolution is unavailable, the only operationally accessible information is what was already simultaneously specified, which by structural necessity is the boundary content.

The resonance is suggestive rather than identifying. VERSF is not deriving the holographic principle, and the holographic principle is not deriving VERSF. The shared structural fact is:

Bulk depth, considered as accessible physical information, requires sequential causal resolution.

Holography says the bulk's information content *can be* encoded on the boundary. VERSF says the bulk's information content *becomes* effectively boundary-encoded when the substrate processes that would constitute sequential resolution are removed. Both pictures locate something deep about the relation between depth and dynamics — and the convergence from opposite directions is itself evidence that the relation is structural rather than a feature of any one theory.

8.6 From potential to realised depth

The accessibility framing forces a refinement of the depth concept itself. There are two senses in which a frozen object has depth:

- **Potential depth** — the coordinate, mathematical structure of the interior, which survives in the frozen state.
- **Realised depth** — the operationally accessible interior structure, which requires sequential causal resolution and does not survive.

Realised depth is not a static property an object *has*; it is something that must be continuously *actualised* by substrate activity. Each commitment update along a chain through Λ resolves an additional layer of bulk distinction. Stop the updates and the bulk reverts to causal inertness; depth becomes potential but not actual.

This connects directly to the VERSF principle that commitment events generate physical reality. A static configuration contains *potential* structure; active fact formation is what continuously resolves and realises distinguishable spatial depth. The world is not merely *in* three dimensions. It is continuously *being made* three-dimensional by the substrate's sequential resolution of bulk distinctions.

8.7 What this is and is not claiming

The accessibility argument is precise about its scope:

- **It is not claiming** that the universe becomes literally two-dimensional when frozen, that 3D structure is illusory, or that information is fundamentally lower-dimensional in some metaphysical sense.
- **It is claiming** that the *physical accessibility* of depth requires sequential causal resolution, that this resolution requires substrate updates along Λ, and that in the frozen state the operationally available information collapses to what was already simultaneously specified — which is, by structural necessity, boundary content.

The slogan is therefore not *"frozen reality is 2D"* but rather:

Time is not merely something happening in space. Time is what continuously actualises spatial depth.

This reframes what the temporal "dimension" *does*. It is not a fourth coordinate alongside three spatial ones; it is the substrate's sequential resolution process, without which the three spatial dimensions reduce to potentialities encoded at their boundaries. Depth and dynamics are co-constituted: each requires the other to be physically actual.

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9. Operational Dimensionality: A Formal Argument

We now make the frozen-reality intuition precise. The argument hinges on keeping three different senses of "dimension" apart, so we begin there before introducing the fact-map.

9.1 Three senses of dimension

The frozen-reality argument turns on a distinction the standard literature usually elides. We separate:

1. **Mathematical dimension.** The dimension of the manifold or coordinate space used to describe the object. For the region $R \subset \mathbb{R}^3$ in our setup, this is trivially 3, and remains 3 in the frozen scenario. Mathematical dimension is a property of the representation, not of the object.
2. **Ontological dimension.** What the object *is*, considered as a constituent of physical reality — its standing as a three-dimensional thing in the world, independent of how it is described or probed.
3. **Operational dimension.** The number of independent directions along which the object's distinguishable facts can be probed, compared, and persisted across substrate updates.

The container picture treats (2) as primitive and substrate-independent. On that view, an object simply *has* its ontological dimension; (1) is our representation of it, (3) is our access to it, and the frozen object retains its ontological 3D-ness intact while the operational story is at best epistemic decoration.

VERSF rejects the container picture, and with it the substrate-independent reading of (2). The framework's substantive metaphysical commitment is:

Ontological dimension is operational dimension.

This is not a definitional manoeuvre. It is the claim that there is no further fact about what an object *is* over and above what the substrate has committed about it. Ontology is constituted by commitment, and commitment is operational by construction. There is no "intrinsic being" of objects standing behind the operational facts, because there is no "behind" the substrate — the substrate is what there is. The container picture postulates one; VERSF denies it.

Why the identification is forced rather than chosen. The identification is not a free metaphysical preference. It is the only ontology that avoids a structural cost the alternatives all pay. Consider what it takes to reject it.

Any ontology that grounds physical reality in something *other than* operational distinguishability must specify what that something is. The candidates fall into a small number of patterns, and each carries the same characteristic cost:

- *Substantive non-operational ontology* posits physical facts that are not operationally accessible. Such facts make no difference to what any physical process can detect,

measure, or be constrained by — they constitute physical reality but do nothing physical. This violates the working assumption of all empirical physics: that what is physically real is what physical processes engage with. Either the operationally inert facts nonetheless do explanatory work (unstable, since explanatory work is itself a kind of operational consequence) or they are explanatorily idle (in which case the ontology has bought no benefit by including them).

- *Hybrid ontology* — operational facts plus non-operational surplus — inherits the cost of the non-operational surplus while providing no compensating advantage over the pure operational view. The simpler view is to drop the surplus.
- *Verbal-only ontology* — existence without operational underwriting — is the position §13.2's Option 3 attempts. It empties "physical" of content (the full argument is in §13.2).

The pattern is robust. Any rejection of the identification posits facts that make no operational difference. Whatever theoretical work those facts are alleged to do must either reduce to operational consequences (rendering the non-operational reading redundant) or be itself operationally inert (rendering the work illusory). The identification "ontological dimension = operational dimension" is therefore not a metaphysical choice; it is the position that pays no surplus-structure cost, while every competing position pays such a cost without operational compensation. Rejecting the identification means accepting that physical reality contains facts that make no difference to anything physical — which is not so much an alternative ontology as the abandonment of ontology's connection to *operationally accessible* physics.

This argument is internal to the operational view rather than external to it; its force is to show that the view is self-consistent under pressure and that its competitors pay surplus-structure costs *by their own lights*, not to derive the identification from premises a critic would grant independently. A structural realist who takes mathematical structure to ground physical reality regardless of operational accessibility would reject the framing here at the same step §9.1 invites them to reject — the move from operational accessibility to the constitution of physical content. That disagreement is not addressed by the constraint argument; it is the disagreement the constraint argument presupposes.

With the identification in place, the frozen scenario does the work asked of it. Mathematical dimension survives because it is a property of representations, which we can write down whether or not the substrate is active. Ontological-cum-operational dimension does not survive, because the substrate processes that would constitute it are absent. The familiar "but it's still 3D" intuition tracks (1), not (2). The frozen object remains *describable* but is not *anything*.

The remainder of §9 formalises sense (3). The identification (2) = (3) is the metaphysical commitment that licenses reading the resulting formal argument as ontological rather than merely epistemic.

9.2 Facts, fact-maps, and the update parameter

Coarse-graining caveat. The formalism that follows takes $R \subset \mathbb{R}^3$ as the spatial domain over which fact-maps are defined. This is a *coarse-grained* representation. By the arguments of §6.2 and §11, R is itself a reconstruction from substrate activity, not a domain given prior to it: space

emerges from adjacency relations produced by recurring commitment events, with the substrate's interface-likeness preventing any bulk-level pre-spatial container from being simultaneously committed at any Λ-position. The §9 apparatus operates at the coarse-grained level where R has already been reconstructed; it makes the rank-of-fact-variation argument workable but does not assert spatial primitivity. The substantive ontological commitments are in §6.2 and §11; §9's formalism is downstream. With this bracketing in place, the formal argument can proceed without reintroducing the substantivalism §6.2 dismissed.

Represent an apparent three-dimensional object by a set of distinguishable facts

$$O = \{ f_i \}, i \in I,$$

where each f_i is a committed distinction — something the substrate has identified, can compare with other distinctions, and persistently relates to those distinctions. In VERSF terms, each f_i is generated by a fold or a coarse-grained collection of folds.

A static geometric description assigns O a region $R \subset \mathbb{R}^3$. But this alone does not constitute a physical three-dimensional object. We need a **fact-map**

$$F : R \times \Lambda \to S,$$

where S is the space of committed states and Λ is the ordered update parameter — *not* fundamental time, but the intrinsic ordering of commitment events on the interface.

9.3 The condition for operational existence

For O to be operationally real, F must support distinguishable variation. Either

$$F(x, \lambda_2) \neq F(x, \lambda_1)$$

(facts change), or

$F(x, \lambda_2) = F(x, \lambda_1)$ with persistence itself recorded by some fold

(facts persist, and that persistence is registered). Either way, there must be an ordered pair (λ_1, λ_2) with $\lambda_2 > \lambda_1$ along which some fact is established.

Without this — when Λ is empty or $\partial F/\partial \lambda \equiv 0$ with no recorded persistence — O has no operational content. It is a configuration, not an object.

9.4 Operational dimension via fact-comparison

Define the **operational dimension** of O as the number of independent spatial directions along which distinguishable facts can be probed, compared, and updated. Let $d_x F$ denote the spatial differential of F at a point. We say O is operationally three-dimensional when

rank(d_xF) = 3,

i.e. there exist three independent spatial directions e_1, e_2, e_3 along which F varies linearly independently in S.

Now — and this is the crucial step — the spatial differential d_xF is operationally meaningful only through ordered comparison. The comparison itself is a fact-forming process:

C_{ab}(λ) = C(F(x_a, λ), F(x_b, λ)),

and its persistence requires the record-level difference

C_{ab}(λ_2) − C_{ab}(λ_1)

to be either non-zero or recorded as invariant across the update. A spatial gradient that no substrate process can ever compare or record is not a physical gradient; it is a coordinate fiction.

9.5 The frozen-reality conclusion

In the frozen scenario, by definition

$\partial F/\partial\lambda = 0$, $\partial C_{ab}/\partial\lambda = 0$, $\partial\rho/\partial\lambda = 0$.

Therefore no comparison facts form, no record-level differences arise, and the spatial differentials d_xF are operationally void. The mathematical rank of d_xF may still equal 3, but **operationally** the dimension is undefined:

$\Lambda = \emptyset \Rightarrow$ D_op(O) is operationally undefined.

This is the formal content of the frozen-reality argument. It does not say that three-dimensional geometry is unreal. It says that **three-dimensional physicality requires distinguishable facts that are comparable and persistent across an ordered update structure**. Pull out the ordering, and physicality collapses to mathematics.

9.6 The reconstruction chain

Putting the pieces together, the operational chain is:

3D physical object ⇒ persistent distinguishable facts ⇒ ordered record structure ⇒ emergent temporal flow.

The illusion is not that the object exists in three dimensions. The illusion is that the ordered update structure must be a fundamental flowing time dimension. In VERSF, it isn't; the ordering is supplied by commitment events on the substrate, and the dimension we call "time" is the parametrisation of those events at coarse-grained scale.

10. The Commitment Interface and the Accessibility of Time

The accessibility argument of §8 examined what is physically accessible *across space* at a given commitment moment, and traced the way operational depth depends on sequential resolution. This section examines its temporal counterpart: what is physically accessible *across time* at any given moment of substrate activity. The two arguments are structurally parallel, and together they form the operational core of the VERSF reading. The temporal version is the deepest of the three pillars because it makes operational reality irreducibly interface-like at every moment, not merely at moments of frozen suspension.

10.1 The interface as physically active substrate

The deepest physically active layer of VERSF is the commitment interface. It is the substrate on which:

- loops form and carry transport structure,
- folds commit and become irreversible,
- records accumulate into $\rho(x, \lambda)$,
- and coarse-grained geometry emerges by reconstruction.

The interface is *not* static. Its continuous updating is what generates operational continuity, causal ordering, persistence, and temporal experience. This reframes the architecture of physical theory:

Rather than

space + time → events,

VERSF proposes

sequential commitment events on the interface → experienced spacetime.

The interface is therefore not "in" space and time. Space and time are coarse-grained re-descriptions of what the interface is doing.

10.2 What is physically accessible at any operational moment

At any operational moment — any position in Λ — what is physically accessible to any system in the universe?

The standard block picture posits an extended four-dimensional manifold in which past, present, and future events all exist with equal status. The operational question is sharper: which of these is causally available to any physical process at this moment?

- The past is not directly accessible. Whatever the past was, it is no longer available for physical interaction. No present system can causally affect, exchange energy with, or receive information directly from a past event. We do not now physically interact with the Cretaceous period.
- The future is not yet accessible. Whatever the future will be, it has not yet committed. No physical process can currently exchange energy, momentum, or information with events that have not yet happened.
- Only the **locally committed slice** of reality is operationally available. Every signal received, every interaction performed, every measurement registered — all are events at this position on this commitment chain.

This is not a claim about observers or perception. It is structural and causal. The light from a distant supernova reaches us *now*, in this committed slice — even though it carries information about a star that long since ceased to exist. The information is present; the original event is not. A geologist examining a Cretaceous fossil is interacting with a present rock arrangement, not with a dinosaur. The substrate's causal structure exposes only the locally committed slice plus the records it carries.

The principle generalises:

Along any commitment chain through Λ, physical accessibility at any chain-position is confined to the locally committed slice plus its order-ideal of records and its antichain of unrealised potentialities; past and future are not simultaneously accessible physical domains but are represented only through records and unrealised potential respectively.

This holds for every system, every physical interaction, every measurement apparatus, and every causal process whatsoever, on every chain. Nothing inside the universe ever physically encounters the four-dimensional block as a totality. The block view's central claim — that all events equally exist simultaneously — is, on the operational reading, a claim that no physical system on any chain in the universe can ever instantiate or verify.

10.3 Memory, records, and prediction are present structures

A natural objection arises immediately: surely we *do* have access to the past, through memory, fossils, photographs, recorded data? And surely we have probabilistic access to the future through prediction?

This objection mistakes the structure of these phenomena. None of them is access to the past or future as such. They are all present structures.

- A **memory** is a present neural configuration, causally produced by past commitment events but operationally accessible *now*. It is not a window into the past; it is a present record formed at past λ-positions and persistent into the present.
- A **fossil** is a present rock arrangement, causally produced by a long-dead organism but operationally accessible now. The dinosaur is not in the rock; a *trace* is.

- A **photograph** is a present pattern of pigments or pixels, causally produced by light from a past event but operationally accessible now.
- A **prediction** is a present computation about possible commitments not yet made. The future has not happened; what we have is a present structure modelling a range of possible futures.

In every case, what is operationally accessible is a *present* structure that *encodes* information about temporally distant events. This is exactly what one expects on the VERSF picture: records accumulate in $\rho(x, \lambda)$, and at any λ-position the accumulated record structure is present and available. The past itself is not.

This sharpens the critique of the block view considerably. The block needs all events to equally exist *simultaneously*, but nothing in the universe ever instantiates that simultaneity. Every causal access to a "past event" is in fact access to a present trace; every causal access to a "future event" is in fact access to a present anticipation. The 4D simultaneous existence of events is a feature of a mathematical representation, not of any operational state of affairs.

10.4 Mathematical spacetime versus operational reality

This invites a distinction parallel to the trichotomy of §9.1 but applied to spacetime as a whole:

- **Mathematical spacetime** is a four-dimensional manifold M with appropriate geometric structure. It is a useful representation. Whether it exists "as a totality" is a question about the representation, not about the world.
- **Operational reality** is always interface-like: along any chain through Λ, what is physically accessible at any chain-position is the locally committed slice plus the records and potentialities adjacent to it. The four-dimensional totality is never the operational state.

The block universe identifies (1) with reality and treats (2) as either psychology or coarse-grained appearance. VERSF inverts the priority: (2) is the operational state of affairs, and (1) is a powerful mathematical representation that abstracts away the operational interface in the way a film strip abstracts away the projection.

This is the temporal analogue of §8's spatial accessibility argument. Just as a mathematically 3D cube has only 2D-worth of operationally accessible information at any moment, mathematical 4D spacetime has only the interface-worth of operationally accessible structure at any moment. In both cases, the "extra dimension" beyond the operationally accessible is real as mathematics and as recovered structure across substrate updates — but not present as simultaneous physical accessibility.

10.5 The moving informational boundary

The picture that emerges is striking. Reality, operationally considered, is not a static four-dimensional object. It is a *moving informational boundary* — along any commitment chain, the locally committed slice — together with the records its passage has accumulated and the

potentialities not yet committed in front of it. There is no single such boundary; there are many, one per chain through Λ. Substrate activity is the motion of these boundaries; record growth is what each boundary leaves behind.

This image must be qualified carefully against the §6.1 treatment of Λ. The moving boundaries are *not* a single global surface advancing along a preferred axis. Λ is a partial order, not a linear parameter, and there is no substrate-level global "now". Different regions of the interface support different commitment chains, and each boundary is local to its chain. What is true is that *along any commitment chain* through Λ, what is operationally accessible at any position is the committed slice plus the order-ideal beneath it (the records) plus the antichain structure above it (the unrealised potentialities). The relativity of simultaneity follows naturally: there is no single boundary because there is no single chain that picks out a preferred foliation.

Even with this qualification, the structural claim is decisive: physical reality is never given as a four-dimensional totality. It is given only through actively updating commitment surfaces — local to each chain through Λ — whose ordered reconstruction generates the appearance of temporal extension.

10.6 What this is and is not claiming

The temporal accessibility argument is precise about its scope:

- **It is not claiming** that the past did not happen, that the future cannot be anticipated, or that there are no facts about temporally distant events. The past is real in the sense that records of it persist in ρ; the future is real in the sense that constraints on what can be committed are operative now.
- **It is not claiming** that this is a phenomenological or observer-relative point. The argument is structural and causal: it would hold identically in a universe with no observers whatsoever. The "limitation" is built into causality itself, not into perception.
- **It is not claiming** that there is a preferred global "now" that advances. The partial-order structure of Λ blocks that reading; what is local is the accessibility, not a substrate-wide simultaneity.
- **It is claiming** that along any commitment chain through Λ, physical accessibility at any chain-position is confined to the locally committed slice plus its records and adjacent potentialities, that past and future are operationally present only through records and potentialities, and that the four-dimensional totality posited by the block view is never instantiated as an operational state of affairs.

The slogan, parallel to §8.7:

The universe is never physically encountered as a four-dimensional totality. It is encountered only through actively updating commitment surfaces — one per chain through Λ — whose ordered reconstructions generate the appearance of temporal extension.

Together with the spatial slogan of §8.7, this gives the central operational pair: *depth is constructed across moments, and time is constructed across the records left by their succession*. Both involve a mathematical "extra dimension" that is never operationally simultaneous; both involve substrate activity that constructs the experience of that dimension through ordered updates. Mathematical spacetime may be 4D. Operational reality is always interface-like.

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11. Why the Substrate is Interface-Like

The arguments of §§8 and 10 establish that operational reality is interface-like — depth is constructed across moments, time is constructed across the records left by chain progression, and at any Λ-position what is accessible is the locally committed slice plus its adjacent records and potentialities. But the paper has so far *asserted* the interface-likeness rather than *derived* it. This section closes the gap. The substrate is interface-like not by stipulation, not as analogy, not because "reality is literally flat," but because **simultaneous physical accessibility structurally privileges boundary commitments over fully realised bulk states**. The interface is structurally necessary, not decorative.

This restores the substrate-and-interface as the central actor of the paper, with causal continuity (§12) supplying the mechanism by which interface updates reconstruct bulk depth, and the comparisons with alternatives (§13) drawing their force from both.

11.1 The structural asymmetry between bulk and interface

Recall the structural fact established in §8.1. Information defined on a boundary is accessible by *simultaneous specification*: a surface fact is given all-at-once, without traversal. Information defined in the bulk is accessible only by *sequential causal resolution*: a signal must propagate inward, a comparison must traverse from layer to layer, a measurement must resolve one depth after another.

This asymmetry has a consequence the earlier sections did not draw out. Consider what it would mean for a substrate to *simultaneously host* a fully realised bulk state — to commit, at a single position in Λ, distinctions distributed across the full depth of a three-dimensional region. By the asymmetry above, those distinctions are not boundary-level; they are bulk-level. Bulk-level distinctions require sequential causal resolution to constitute. But sequential causal resolution *is* the chain — it requires multiple Λ-positions linked by causal inheritance, not a single position.

So bulk-level distinctions cannot be committed simultaneously: their very constitution requires the chain structure, which is exactly what simultaneous commitment lacks. Within a substrate-first dynamicist framework — one in which commitment requires substrate activity and substrate activity is what constitutes facts — simultaneous bulk commitment is incoherent: the substrate would need to be doing what it has not yet done.

This conditional structure is worth being explicit about. Tenseless frameworks dissolve the apparent incoherence by giving up substrate-first dynamicism: in a tenseless self-consistent four-

dimensional structure, "having already done what is now being done" is just what consistency requires, and the apparent circularity is resolved by giving up the temporally directed reading of "doing" altogether. The cost is the operational arguments of §§8 and 10 — tenseless frameworks face the §13.2 trilemma. The §11 argument is therefore *conditional on the substrate-first reading*: it does not deliver interface-likeness from neutral premises but shows that interface-likeness is the structural consequence of taking substrate dynamicism seriously. The §§8, 10, and 13.2 arguments together do the work of motivating substrate-first dynamicism; §11 then shows what shape the substrate must take if that dynamicism is accepted.

The conclusion, properly conditioned, is:

Within a substrate-first dynamicist framework, a substrate's simultaneously committed content can only be boundary-level. Bulk depth must be reconstructed across updates, not contained within them.

11.2 Interface-likeness as a structural necessity

Bridging accessibility and constitution. Before drawing out the necessity claim, the inferential structure of §11.1 needs to be made explicit. The argument moves from the §8.1 *accessibility* asymmetry (boundary information is given all-at-once to processes; bulk information requires sequential probing) to a *constitution* asymmetry (boundary commitments can be simultaneous; bulk commitments cannot). This move is licensed by the §9.1 identification of ontological with operational dimension: there is no constitution of distinctions independent of their accessibility to substrate processes. Without that identification, accessibility-asymmetry would be a fact about how processes interact with already-constituted bulk distinctions, leaving open the possibility that the substrate commits bulk-level distinctions which are then only accessible by sequential resolution. With the identification, accessibility *is* constitution: a distinction that cannot be operationally accessed without traversal is a distinction that cannot be operationally committed without traversal. The §11.1 derivation therefore inherits §9.1's metaphysical commitment; it is not an independent argument from neutral premises but a structural consequence of the operational-ontological identification.

This explains why the substrate is interface-like at every position in Λ. The interface is not a contingent feature of the VERSF picture, nor an analogy borrowed from holography, nor a metaphor for our limited perception. Given substrate-first dynamicism (§§8, 10, 13.2) and the operational-ontological identification (§9.1), the interface is the *only kind of operational structure* capable of simultaneously hosting committed distinctions without requiring prior traversal through an already-realised bulk.

Put schematically:

- If the substrate's commitments at any Λ-position could be fully bulk-like, the bulk's constitution would already require the chain — circularly requiring the substrate to have prior access to its own subsequent activity.

- If commitments are restricted to boundary-level (interface) distinctions, no such circularity arises: each Λ-position commits boundary content, and chains of such positions reconstruct bulk content through causal continuity (§12).

The interface is therefore the structurally minimal — and structurally maximal — content a single Λ-position can host. Less than this would not constitute a commitment slice at all; more than this would require the chain to be already present at every position. The substrate's commitments must, by structural necessity, take the interface form.

This also closes the gap in §10's argument. Operational reality is interface-like along every chain through Λ not as an observational limitation, not as a coarse-graining effect, and not because we happen to lack access to a "deeper" bulk-level substrate state — but because no such state is structurally available to be committed in the first place. There is no bulk-level substrate state for the chain to construct from; there is interface activity from which chains reconstruct bulk-level structure.

11.3 Holography as consonance, not derivation

The argument of §11.1–§11.2 sharpens the holographic resonance flagged in §8.5 without elevating it to entailment. It is worth being explicit about what the §11 argument does and does not deliver, because the temptation to overclaim is real.

What the §11 argument actually delivers, within substrate-first dynamicism: substrate commitments must be interface-like at each Λ-position, and bulk depth must be reconstructed across chains. That is a structural fact about substrate ontology.

The holographic principle in contemporary physics says much more specifically: the bulk information content of a region — its states, observables, dynamics — is encoded in a precise mathematical equivalence on the bounding surface, with specific dictionaries between bulk and boundary operators. AdS/CFT in particular provides this kind of precise encoding, with specific gauge-gravity correspondences that are part of the content of string theory rather than derivable from any general structural claim.

The VERSF structural fact does not deliver this specific content. What it does deliver is the *kind of fact* of which the holographic principle could be a more specific instance:

Bulk information that cannot be simultaneously committed at any single operational position must, if it is operationally accessible at all, be carried by structures that can be — namely boundary commitments and the chains relating them.

Whether the specific form holography takes in AdS/CFT or related programmes is the quantum-theoretic specification of this structural fact, or a contingent feature of specific theories that happens to converge with it, is a question for the physics of those frameworks — not something §11 settles. What §11 establishes is that holographic behaviour is *consonant* with the structural argument, and that the structural argument supplies a reason why such behaviour might be widely instantiated rather than a coincidence peculiar to string theory.

The earlier §8.5 framing of "shared structural fact" / "convergence from opposite directions" is therefore the right one. This section refines but does not exceed it: VERSF does not derive holography, and a careful reader should not infer otherwise from §8.5 or this section. The convergence is real and informative — both pictures locate the same structural fact about bulk information requiring boundary carriage — but the specifics of holographic encoding remain proprietary to the theories that work them out in detail.

11.4 Visualising the architecture: cymatics

A vivid visualisation comes from cymatics — the phenomenon in which fine material (sand, salt, water) placed on a vibrating two-dimensional plate spontaneously organises into intricate geometric patterns. Strike a metal plate, vibrate it at the right frequency, and the sand on it gathers itself into delicate nodal patterns: rosettes, lattices, stars, mandalas. Change the frequency and the pattern reorganises into something different. Stop the vibration and the pattern persists as a *static residue* of the last active state — the sand sits in the nodal positions where the most recent activity placed it, but no new structure forms; the demonstration ceases to be a demonstration of pattern *formation* and becomes a record of one. The same plate at different frequencies produces utterly different worlds of pattern; which pattern appears is determined by the driving activity, not by anything intrinsic to the plate when at rest.

Cymatics illustrates the VERSF architecture with unusual directness, because the plate *literally is* a 2D interface. The structural features the rest of this paper has had to argue for — interface-likeness, relational reconstruction, coherence-essential, void-as-potential — are present in the physics of the demonstration itself, not as illustrative simplifications.

The plate is the 2D interface. Everything happens on this thin two-dimensional surface. There is no bulk activity; the plate is the locus of all events. Each grain of sand is at the interface; the patterns form at the interface; the dynamics happen at the interface. This is not analogy by approximation. The plate's two-dimensionality is the structural fact §11.1–§11.2 derived for the substrate, manifested as ordinary physics.

The vibration is the causative signal — the substrate's activity. Without applied vibration, the plate is inert — its sand either in initial disorder, or sitting as residue from past driving. Neither state involves *current* commitment activity. With vibration, the interface becomes active: it commits a structure of nodes and antinodes, and the sand finds its place in relation to that committed structure. The vibration is what brings the plate's interface aspect into commitment activity; the plate is the substrate in both states — undifferentiated potential when at rest, active commitment locus when driven.

The patterns emerge relationally, not by design. No external agent decides "put sand here, put sand there." Each grain finds its position by the dynamics — the local nodal structure, its relationship to neighbouring grains, the chain of micro-displacements that propagate across the plate as it vibrates. The pattern is the time-integrated effect of these relational adjustments. This is precisely the §6.2 relational-identity claim made visible: each grain's position is determined by the relational whole, not by anything intrinsic to the grain.

The actively formed pattern is what the plate is doing, not what it intrinsically contains. A still plate does not "contain" any specific pattern; which pattern emerges depends entirely on which driving signal is applied. While the plate vibrates, the visible pattern is being *continuously regenerated* by the chain of relational adjustments — the pattern is what the plate-and-driving-system *is doing*, not a property it possesses at rest. Stop the driving and the active formation ceases. The most recently formed pattern then persists as a static residue on the plate, but this residue is a *record* of past activity, not active reality: it shows where the substrate was committing, not what the substrate is now committing. The residue is durable; the active formation is not. This is the §6.2 fold-as-process and §12 chain-not-slice points compressed into a tabletop demonstration, alongside the §10.3 point about records: realised reality is what the substrate is *currently doing*; the records of past commitments persist as present structures without themselves being active reality.

Coherence is essential. Coherent vibration at a definite frequency produces ordered patterns. Random noise vibration produces chaos — the sand jiggles but does not organise. The difference is not in the *energy* input but in the *coherence* of the driving. This is exactly the §12.2 and §12.7 distinction: ordered substrate activity produces realised structure; uncorrelated activity produces formless agitation. The two failure modes (frozen and decoherent) are visible on the same plate, in the same demonstration.

Different drivers produce different chains. Different driving signals on the same plate produce different patterns. Multiple plates driven at different frequencies produce different patterns simultaneously. There is no global pattern across all plates; each plate-and-driver system runs its own chain of relational adjustments and produces its own structure. This is §12.6 locality of becoming made visible: each plate has its own accumulated pattern history, not a shared one.

The mapping to VERSF is direct:

VERSF concept	Cymatic analogue
The void = the substrate	The plate itself — the unvibrated state is the void aspect (undifferentiated potential), the vibrating state is the active substrate aspect; same plate, different dynamic conditions
A fold	A node/antinode commitment event
The interface	The plate surface (literally 2D) — where commitments occur
The causative signal	The driving vibration
Λ (partial order)	The order-structure of relational adjustments
A chain through Λ	The propagation sequence of adjustments across the surface
Bulk depth	The apparent extended pattern reconstructed from continuous adjustment
Records	The sand positions — present during driving and *persisting as static residue* after cessation
Frozen reality	Vibration stopped; the static residue persists but no new commitments occur

VERSF concept	Cymatic analogue
Decoherent reality	Noise driving; agitation without form
Multiple chains	Multiple plates driven at different frequencies

The analogy reaches deeper than the structural mapping. In cymatics, the pattern is *not contained in the plate*: you cannot tell what pattern will form just by examining the plate at rest. The pattern emerges from the *relationship* between the plate's properties and the driving signal — a relational reality that exists only while the relation is being actively sustained. This is the VERSF picture compressed into a tabletop demonstration. Reality is not in the substrate. Reality is what the substrate is *doing in relation to its causative activity*.

Three further features become vivid.

First, *the void as potential rather than absence*. An unvibrated plate is not "empty"; it contains the latent possibility of every pattern its geometry can support. The void in VERSF (§6.2) is similarly not absence but undifferentiated potential — the unactivated substrate condition out of which commitment differentiation produces realised structure. The unvibrated plate and the void are the same kind of thing: a symmetric ground from which asymmetry-events differentiate to produce structure.

Second, *each grain's place is determined by the relational whole, not by anything intrinsic to the grain*. No grain has an "intrinsic" location; each finds its position by the nodal structure of the entire plate. This is the §6.2 relational-identity point made visible at the level of individual elements: identity is positional, not intrinsic, and what individuates one grain's contribution from another's is its place in the relational whole.

Third, *the cymatic pattern recovers under disturbance while driving continues*. Briefly disturb the plate (push a finger into the sand) and the pattern reforms — provided the vibration continues. The pattern is robust *because* it is sustained by the chain of relational adjustments, not because it is rigidly held in place. This is what realised reality looks like on the VERSF view: not a fixed structure clinging to existence but a continuously regenerated relational pattern, robust precisely because of its dynamism.

The disanalogies are the familiar ones, with one worth flagging explicitly because a careful physicist reader will notice it. The plate exists in pre-existing space-time; VERSF proposes that this kind of pattern is what *constitutes* space-time. The driving vibration is external to the plate; in VERSF the substrate's causative activity is internal to itself, with the void as the symmetry condition from which asymmetry-events emerge (§6.2) rather than as an external driver. A third disanalogy: cymatic patterns are *deterministic responses* to fixed driving frequencies — the steady-state response of the plate's modal structure to a given input, mathematically derivable from modal analysis without running the dynamics. VERSF commitments, by contrast, are genuinely *productive*: records grow monotonically along chains through Λ, and later commitments are not derivable from boundary conditions alone — prior record content constrains but does not determine subsequent commitments. A sceptic could press this and say:

"Your favoured analogy actually shows that bulk reality is derivable from boundary conditions; the chain is convergence to a pre-determined attractor, not genuine becoming." The reply is that the cymatic analogy is selected for the structural points it does make — interface-likeness, relational reconstruction, coherence-necessity, dynamic sustenance — and not for the question of whether substrate commitment is derivable from prior conditions, which is a separate VERSF claim the analogy is not asked to illustrate. These are the standard limitations of any analogy in which a thing within reality is used to illustrate the constitution of reality. The structural features the analogy does highlight are robust under these caveats, and unusually so for cymatics because the interface-likeness is literal physics rather than approximation.

Cymatics is perhaps the closest tabletop demonstration of the VERSF architecture available. When the abstract picture starts to feel out of reach, the right visualisation to return to is the vibrating plate with its emerging patterns: thin active interface, structure continuously regenerated by coherent relational activity, residue persisting as static record once cessation occurs (records remain; the active formation ceases), pattern losing form under decoherent driving, multiple plates producing different structures independently, and the *actively formed* pattern being what the system is *doing*, not what it intrinsically *contains*. The world, on the VERSF picture, is the most fundamental instance of what one already sees on a vibrating Chladni plate: realised structure is the relational shape produced when the substrate, in its 2D active aspect (the interface), commits asymmetry-events out of its own undifferentiated potential (the void).

11.5 The architectural picture

With the structural argument in place, the architecture of VERSF can be stated cleanly. Six levels, each playing a distinct role:

Level	Role
Void / substrate	The single fundamental reality; symmetric undifferentiated potential in its inactive aspect, active substrate in its committing aspect
Interface	The substrate's 2D active aspect; simultaneous committed accessibility at each position in Λ
Chain continuity	Reconstruction of structure across causally linked interface updates
Bulk depth	Emergent operational reality across chains
Time flow	Reconstruction effect of monotonic ρ-growth along chains
4D spacetime	Mathematical abstraction over the chain structure

The hierarchy is not a list of distinct ontological levels in a stack, but a description of what does what. The substrate is one thing; its activity has these distinguishable aspects. The interface is what is simultaneously committed; the chain is what successive commitments produce; bulk depth, time flow, and 4D spacetime are increasingly coarse-grained descriptions of the chain's accumulated activity.

The central sentence is now stateable directly:

The substrate behaves interface-like because simultaneous physical accessibility structurally privileges boundary commitments over fully realised bulk states; bulk dimensionality is reconstructed only through coherent causal continuity across successive interface updates.

This sentence connects the paper's threads. The 2D accessibility intuition (§8) is reframed as the structural privileging of boundary commitments. The frozen-reality arguments throughout become arguments about what fails when chain reconstruction is removed. The chain ontology of §12 is the reconstruction mechanism. The holographic resonance is consonant with this picture, though not derived from it (§11.3). The temporal accessibility of §10 is the chain-local form of interface-likeness. The local slices of §12 are interface commitments at successive Λ-positions, individuated in the distinction-ontological key of §6.2.

The substrate-and-interface returns to the centre of the picture as the constitutive layer; causal continuity is what links its updates; bulk reality is what those linked updates reconstruct.

Methodological note: the package character of the argument. The architecture just stated is mutually supporting in a way worth making visible. Tracing the chain of motivations: the §11 derivation of interface-likeness is conditional on substrate-first dynamicism (§11.1); substrate-first dynamicism is motivated by §§8 and 10 and the §13.2 trilemma; the §13.2 trilemma turns on the instantiation requirement; the instantiation requirement is the §13.2-level expression of the §9.1 identification of ontological with operational dimension; and the §9.1 identification is what makes the operational arguments of §§8 and 10 transfer from accessibility to constitution and thereby motivate substrate-first dynamicism. The moves form a *package* rather than a strictly linear chain. This is not a defect — the moves do genuinely cohere as a single picture — but the package character should be visible to the careful reader. The claim is not "each piece independently motivates the next." The claim is that the package as a whole has more operational adequacy, more predictive content (via VERSF's wider programme), and more philosophical economy than the competing pictures of §13. A reader who grants the package can run the argument forward through §§8–13; a reader who does not has independent work at the package level — primarily at §9.1's metaphysical identification — rather than at any single derivation step. **Appendix A** makes the package character maximally explicit: it derives the major VERSF claims (distinction-ontology, operational ontology, partial-order structure, antichains/non-locality, interface-likeness, chain continuity, monotonicity, anti-block) from a single foundational principle, showing the architecture as the structured unfolding of one ontological commitment rather than a list of independently-supported claims. **Appendix B** supplies the corresponding minimal formalisation, with definitions of Λ, operational distinguishability, records, operational dimension, and the interface theorem, together with proof-sketches for the key propositions.

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12. Causal Continuity and the Emergence of Realised Reality

The accessibility arguments of §8 and §10 establish that operational depth and operational temporal extent each require ordered updates rather than single static states. The interface-likeness argument of §11 explains why the substrate must take this form structurally. This section identifies the deeper principle that connects them all: realised spatial dimensionality is not encoded in any isolated instantaneous state but emerges from *coherent causal continuity across informational updates*. The chain is not merely a sequence of slices; it is a sequence of slices linked by relations of causal inheritance, and it is this causal coherence that does the constructive work. Once this principle is stated explicitly, the §8, §10, and §11 results emerge as facets of a single underlying claim, and the critique of the block universe in §13 becomes correspondingly sharper.

A note on language. The discussion that follows uses the vocabulary of "slices," "chains," and "inheritance relations between successive states." This language is convenient but, in the distinction-ontological key of §6.2, must not be read as positing slices and states as independent objects between which inheritance is some external relation. A "slice" is the substrate's recurrent asymmetry process considered at one position in Λ — a cross-section of its activity, not a thing the activity inhabits. A "chain" is the substrate's activity considered across a sequence of such positions related by causal dependence — a path through the partial order Λ, not a series of independent items strung together. Inheritance, on this reading, is internal to the substrate's process, not a relation between separable carriers. With this in place, the slice-and-chain language can do its illustrative work without reintroducing the object-ontology §6.2 dismissed.

12.1 What a single slice contains, and what it does not

Consider any single momentary commitment slice on the interface — the state of substrate facts at one position in Λ. The slice contains:

- the committed facts at that position;
- the spatial relations among those facts;
- whatever records have accumulated up to that position.

The slice does *not* contain:

- evolution, because evolution is a relation between states;
- propagation, because propagation requires a destination state;
- persistence, because persistence is the survival of a fact across update;
- motion, because motion is fact-change along a chain;
- realised three-dimensional depth, because realised depth is — by the §8 argument — a relational structure across moments.

A single slice is a state, not a story. What appears as a three-dimensional physical thing in our experience contains essentially nothing of the dynamical content that makes it operationally real. The full content requires the chain.

12.2 Causal continuity, not mere sequence

The chain matters not because it is sequential but because it is *causally continuous*. An arbitrary sequence of unrelated slices would supply temporal ordering without supplying physical reality. What VERSF requires — and what the accessibility arguments tacitly relied on — is more specific:

- successive slices stand in relations of *causal inheritance*: the committed facts at later positions are not arbitrary but are constrained by the committed facts at earlier positions through the substrate's dynamics;
- comparison relations between slices are preserved as records: the inheritance is registered, not lost;
- the propagation of structure across updates is *coherent*: a fold at one position has a determinate relation to corresponding folds at neighbouring positions.

It is this coherent causal continuity that generates operational depth, persistence, and motion. A "frozen" universe is one in which the chain has broken; a universe with random uncorrelated slices would equally fail to produce physical reality, despite formally containing a sequence. What does the constructive work is the causal coherence of the chain, not its bare existence.

This sharpens the operational picture meaningfully. It is not merely that updates are required (as §6 and §10 established) but that the updates must be *causally linked* in a way that preserves structure across the chain. The chain has to *hold together* informationally for reality to be realised.

12.3 Connection to existing physics: state plus transition

This principle has a clean point of contact with how modern physics already treats reality. State alone is insufficient to specify a physical system; what matters equally is the law governing transitions between states. Quantum mechanics, classical mechanics, and field theory all share this architecture: state + transition rule. Reality is not a state; it is a state-and-its-evolution, and neither half is dispensable.

VERSF generalises this insight at a deeper level. The transition rule in standard physics is typically a fixed external law applied to a state space; VERSF locates the resource for transitions in the substrate's commitment dynamics, and shows that the *operational content* of the state itself depends on the continuity of its updates. In standard physics, the state has content independently of the transition rule; in VERSF, the state's operational content is constituted by its participation in the chain.

The convergence is significant. Physicists have always treated dynamics as essential, not optional. The present argument explains why: dynamics is not a supplement to state but the constitutive source of state's operational content. The principle articulated here is therefore not foreign to physics' working assumptions; it makes explicit something physics has been quietly relying on all along.

12.4 The principle behind the accessibility arguments

With this in hand we can articulate the principle behind §8 and §10:

Spatial dimensionality is not fully encoded within isolated instantaneous states, but emerges from coherent causal continuity across informational updates.

The spatial accessibility argument (§8) was an instance: bulk depth requires sequential causal resolution, and "sequential causal resolution" just is the propagation of information across causally linked slices. The temporal accessibility argument (§10) was an instance: physical reality is always interface-like because the operational state at any moment is *one slice*, and the rest is reconstructed from the causally continuous chain in which that slice participates. Both arguments rely on the same underlying fact: depth and persistence live in the chain, not in any single link.

The principle, once stated, also answers in compressed form the natural objections to a slice-based ontology — that frozen instants contain only state, that dynamics is what links slices into a chain, that persistence is the propagation of fact-identity across causal continuity, and that causality is fundamental because the chain's causal structure is what gives reality its operational content. These were established in §12.1; the present statement is what they share.

12.5 Connection to relativity

The causal-continuity framing also clarifies the relativistic structure. Different observers do not access different "block views" of a fixed reality. They construct reality from *different causal chains* through the substrate — different orderings of the same partial order Λ, different accessible information horizons, different patterns of causal inheritance. The relativity of simultaneity reflects the fact that there is no single preferred chain; there are many, each generating its own coherent picture of three-dimensional structure across time.

This connects naturally to the partial-order treatment of Λ in §6.1. Different chains through the same Λ-structure correspond to different foliations; each foliation supplies a coherent causal-continuity story; none is privileged at the substrate level. What is the same across foliations is the underlying partial order — the substrate's commitment dependence — and what differs is the chain-by-chain reconstruction of three-dimensional spatial extent.

The view that emerges is neither relationalist in the standard sense nor substantivalist about spacetime. The substrate's partial order is real and frame-invariant; the chains through it are observer-relative; the spatial dimensionality reconstructed along each chain is the operational reality available *to that chain*. Relativity, on this account, is what one expects when realised reality is what coherent causal chains *do*, not what spacetime *is*.

12.6 Becoming is local, not global

The monotonic growth condition $\partial\rho/\partial\lambda \geq 0$ of §6 should be read in the appropriate sense: ρ grows *along each chain* through Λ, but there is no *preferred chain-independent fact* about how

much becoming has "happened" globally. Different chains accumulate at different rates relative to one another (this is what time dilation expresses at coarse-grained scale), and there is no preferred chain whose accumulation defines the substrate's overall progress. Becoming is real and operationally efficacious, but it is real *along chains*, not as a substrate-wide totaliser.

This has consequences worth stating explicitly: there is no *preferred* chain-independent fact of the matter about how "long" the universe has existed; nor is there a single privileged answer to how "much" of reality has been committed. Each chain has its own answer; none is privileged. (Chain-relative quantities can of course be computed — proper-time accumulation along any chosen worldline is well-defined, and inter-chain comparisons are possible in any global Lorentz frame — but none of these provides the substrate-level, observer-independent totaliser the block view implicitly assumes.) The thesis is stronger than it sounds — it locates the reality of becoming firmly *inside* the substrate's relational structure rather than in any totalising temporal parameter outside it. This is the temporal counterpart of §11's interface-likeness conclusion: just as the substrate's commitments are structurally local in space (interface-shaped at every Λ-position), they are structurally local in temporal accumulation (chain-by-chain, with no preferred totaliser). The locality of becoming is not an additional commitment but a consequence of the same structural facts that drive interface-likeness and chain-reconstruction.

12.7 Coherent informational continuity and the quantum-computational analogy

A suggestive parallel to the present framework appears in quantum computation. The comparison is not intended as an identity claim — VERSF is not being reduced to quantum computing, nor is quantum computation being claimed as evidence for the framework. The relevance is structural. Both pictures place explanatory weight not on isolated instantaneous states but on the coherent continuity of relations across evolving informational configurations.

Classical computation encourages an object-like picture of state evolution. At any instant, the system is treated as occupying a determinate configuration of bits, and the computation is often imagined as a sequence of such independent states linked by externally applied rules. Quantum computation behaves differently. The operational power of the computation is not reducible to any isolated intermediate state; meaningful structure exists in the *maintained coherence* of the evolving wavefunction across computational steps. Destroy the coherence and the computation collapses into classical behaviour. The computational content is therefore relational and distributed across the continuity of the process, rather than fully localised within any single instantaneous configuration.

This resembles the structure developed throughout the present paper. A single commitment slice contains state information but not realised persistence, propagation, motion, or operational depth. These arise only through coherent causal continuity across updates. The slice is not independently sufficient; what matters is the maintained inheritance structure linking slices across Λ. Reality, on this reading, behaves less like a collection of isolated static frames and more like a coherently sustained informational process whose operational content exists across the continuity of the chain rather than within any individual cross-section of it.

The analogy can be sharpened:

- In quantum computation, coherence across computational evolution is essential.
- In VERSF, coherent causal continuity across commitment updates is essential.
- In both cases, isolated instantaneous states underdetermine the realised structure of the system.
- In both cases, breaking the continuity destroys the higher-order operational behaviour.

The resemblance is especially striking through the distinction-ontological lens of §6.2. Quantum theory already weakens naive object ontology: identical particles lack intrinsic individuality, quantum fields behave as unified structures rather than collections of separate objects, and entangled systems resist decomposition into independently meaningful local parts. The VERSF framework generalises this tendency further. Slices are not independent ontological units; they are cross-sections of a continuously differentiating substrate process whose operational content emerges only through relational continuity.

This suggests a broader philosophical possibility:

Operational reality may fundamentally be coherence-based rather than object-based.

On such a reading, what appears as stable three-dimensional physical structure is not the persistence of independently existing objects through an external temporal container. It is the maintained coherence of recursively inherited distinctions across chains of commitment updates. Reality is therefore not merely sequential but relationally sustained.

The comparison also clarifies the role of decoherence-like failure modes in the present framework. A frozen universe fails because causal continuity has vanished entirely; a universe composed of random uncorrelated slices would fail because continuity lacks *coherence*. In both cases, operational physicality collapses despite the continued existence of formally definable states. What matters is not merely the existence of states but the maintained coherence of their inheritance relations. This is the §12.2 point about causal continuity, sharpened by the analogy: the chain holds together only if its inheritance relations are coherently sustained, not merely formally present.

The analogy should not be overstated. Quantum computation remains a precisely defined physical formalism operating within standard quantum theory, whereas VERSF is proposing a foundational ontological interpretation of operational reality itself. The claim is therefore not equivalence but structural resonance. Both frameworks point toward the same deeper intuition:

Meaningful physical structure is not fully contained within isolated states but emerges from coherent relational continuity across evolving informational configurations.

This strengthens the central claim of the present paper. Reality is not fundamentally a static geometry populated by persisting objects. Nor is it merely a sequence of independent states. It is a coherently sustained chain of causally entangled informational updates whose maintained continuity generates the operational appearance of persistence, dimensionality, and temporal flow.

12.8 What this is and is not claiming

The principle is precise about its scope:

- **It is not claiming** that 3D geometry literally vanishes when a single instant is considered. Geometry as mathematical structure remains intact; what is missing from a single instant is the operational content that makes the geometry physically realised.
- **It is not claiming** that a "law of transition" external to the substrate must be added. The causal continuity is internal to substrate commitment dynamics; no external lawgiver is required.
- **It is not claiming** that the chain is a linear succession of globally simultaneous slices. The chain is a path through the partial-order structure of Λ; different observers traverse different chains; locality of time is preserved.
- **It is claiming** that realised spatial dimensionality is a property of coherent causal chains, not of isolated states; that the operational content of three-dimensional physicality lives in the chain; and that this is the deeper principle behind both the spatial and temporal accessibility arguments.

The slogan, complementing §8.7 and §10.6:

Reality is not a static geometry but a causally sustained chain of fact-commitment updates.

Spatial dimensionality, on this view, is what coherent causal continuity *does* across a chain of updates. It is not contained anywhere singular; it is the relational shape the chain produces as it sustains itself. The chain is the carrier of physical reality, and the slice is what the chain looks like when one cross-sections it at any single position.

Or, parallel to §8.4's *depth is between, not in*:

Reality is in the chain, not in the slice.

The two slogans together — for space and for time — capture the operational core: dimensionality and reality both live in the relational structure across substrate updates, not in any single state.

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13. Comparison with Block Universe and Timeless Physics

It is worth being explicit about how the VERSF account differs from neighbouring positions.

13.1 The block universe

In the standard block view, all events coexist in a static four-dimensional manifold; temporal flow is treated as an illusion of consciousness; becoming is denied. VERSF agrees that there is no flowing dimension external to events, but disagrees on two counts that §10 makes decisive.

First, becoming is not illusory. Becoming, in VERSF, is the monotonic growth of ρ. The substrate genuinely *adds* records that were not previously there. There is no pre-written 4D manifold; there is a 3+commitment substrate whose history is *produced*, not *traversed*.

Second — and this is the sharper critique enabled by §10 — the block view posits a state of affairs that no physical system in the universe can ever instantiate, verify, or interact with. The simultaneous existence of all events is, by the temporal accessibility argument, never an operational state. Every causal interaction in the universe exposes only the locally committed slice plus its records along whichever chain through Λ the interaction belongs to. The block's central claim is therefore not a description of what the universe *is*; it is a description of a mathematical representation that abstracts away the operational interface entirely. Whether one calls that representation "real" is a question about how one is using the word; what one cannot say is that any physical process in the universe ever encounters reality in that mode.

13.2 The 4D interface problem

The block universe makes a strong ontological claim: past, present, and future events all equally exist as one four-dimensional totality. The accessibility argument of §10 generates a sharp critique of this claim — sharp enough to warrant its own treatment, because it does not merely contest the block's *interpretation* of evidence but its *coherence as a physical thesis*.

The argument turns on a distinction the block view typically elides: the difference between being *mathematically describable* and being *physically instantiated*. The four-dimensional manifold M can be specified precisely in mathematics. The open question is whether M is also *physical* — whether the totality M is a state of affairs in the world, not merely a representation of one.

The instantiation requirement. To be *physically real* (as opposed to merely mathematically definable) is to be instantiated as a state of affairs that physical processes can engage with. A claim about physical reality requires some account of *how* the claimed entity is physically present. This is not verificationism in disguise; it is the requirement that physical claims have physical content, that they cash out in terms of substrate processes, interactions, accessibility — something the world *does*. For a localised physical object, instantiation is uncontroversial. For the four-dimensional block, instantiation is the open question. The block view says all moments coexist; the immediate question is *as what?*

The §9.1 connection. The instantiation requirement is not a free-standing premise. It is the §13.2-level expression of the §9.1 identification of ontological with operational dimension. If ontological facts are operational facts — if a distinction's reality is constituted by its operational accessibility — then to claim something as *physically* real (as distinct from merely mathematically describable) just is to claim that it is operationally instantiated. The instantiation requirement is what §9.1's identification looks like when applied to the question of what a 4D totality would have to be in order to be physical. A reader who grants §9.1 grants the requirement nearly trivially; a reader who does not has independent work to do at §9.1, not at §13.2. The package-character note at the end of §11.5 makes the broader pattern explicit: §13.2's argument and §9.1's identification are facets of one commitment, not independent moves.

The accessibility constraint. §10 established that along any commitment chain through Λ, physical accessibility at any chain-position is confined to the locally committed slice plus its records and adjacent potentialities. No physical system, no matter how constituted, accesses all temporal layers simultaneously. Every interaction in the universe is mediated through the locally committed slice; fossils, photographs, and memories are *present* structures, not direct contact with past events. For the block to be physically instantiated as a totality, there would need to be a physical accessibility structure capable of hosting all temporal layers simultaneously — effectively a four-dimensional interface. But no such interface exists inside the universe.

The trilemma. The block view therefore faces three options, each costly:

1. *Reduce the block to mathematical representation.* Concede that the four-dimensional manifold is a useful mathematical structure but not itself a physical state of affairs. The block becomes a description, not a thing. On this reading, the dispute between VERSF and the block view is not about what reality is but about which mathematical representation is most useful — and VERSF's substrate picture becomes the more fundamental account of what is physically going on beneath the representation.
2. *Posit a 4D physical interface.* Maintain that the block is physically real, and accept that this requires positing a four-dimensional accessibility structure capable of containing all temporal layers as physically simultaneous. The cost: this interface is unobserved, unmotivated, and explanatorily inert. It is a metaphysical posit added precisely to rescue the ontological reading from the operational evidence.
3. *Refuse the instantiation requirement.* Maintain that the block simply *is* — that to be the block universe is to be, full stop, without any further mediating accessibility structure. On this view, physical processes inside the block only access local slices, but the block itself isn't a physical process accessing anything; it just exists. The instantiation requirement is dismissed as a presentist or dynamicist prejudice. (A weaker variant of this option — smuggling in a meta-time or atemporal totality that does the instantiation work — collapses back into a version of Option 2 or reintroduces the very temporal structure the view sought to dissolve, so we focus on the cleaner version.)

Options 1 and 2 cost the block defender substantially. Option 3 — pursued by sophisticated four-dimensionalists in the philosophy of physics literature — needs a direct response, because it refuses the trilemma's framing rather than picking a horn.

The defence of the instantiation requirement. The requirement is that physical claims have *physical content* — that they cash out in terms of substrate processes, interactions, or accessibility structures. Option 3 rejects this and insists that existence and being-accessed-by-something come apart. The response is more pointed than mere appeal to verbal hygiene. *Operational accessibility is what physical content consists of.* The very distinction between a physical claim and a merely mathematical one is that the former has implications for what substrate processes can do, what can be accessed, what can interact — operational implications. Strip the block defender's claim of all such operational implications and what remains is mathematical structure plus a verbal stipulation that this mathematical structure is "real." That is not a competing physical theory; it is a metaphysical preference about which mathematical structures to dignify with the label "physical," and it has no implications for any physical fact.

The §9.1 identification is what makes operational accessibility constitutive of physical content; Option 3 either rejects that identification (in which case the disagreement is over §9.1, not §13.2) or accepts it and faces the requirement that some operational story be told about the block's totality.

VERSF is not contesting whether something one could *call* "the block" could be defined; mathematical structures admit definition. It is contesting whether the block defender's claim is a claim about *physical* reality as distinct from a claim about a useful mathematical representation. Stripped of its connection to substrate dynamics, accessibility, or any interaction with physical processes, the block view becomes mathematical realism plus a verbal preference for calling the mathematics "real." It is, on that reading, no longer in disagreement with VERSF about physics; it is in disagreement about vocabulary.

The instantiation requirement is therefore not a smuggled premise but a *condition for the dispute being about physics rather than language*. Refusing it is permitted, but it costs the block defender the disagreement. With the requirement in place, the original trilemma stands: representation (Option 1), unmotivated meta-interface (Option 2), or verbal-only existence (Option 3). None of the three preserves the original ontological reading of the block as a substantive thesis about physical reality.

A subtler version of Option 3. A sophisticated four-dimensionalist may grant the verbal-dispute point and then press a parallel: yes, the dispute reduces to methodology, but VERSF too posits a structure (the substrate) that is not itself instantiated by anything more fundamental than itself; the same "what is X instantiated as?" pressure applies symmetrically. On this reading both views are making parallel choices — block defenders privilege the manifold, VERSF privileges the substrate — and neither has substrate-external grounds for the preference.

The response is that the parallel is not symmetric. The substrate is operationally accessible in a way the block as a totality is not. The substrate *does things*: physical processes interact with it, commitments happen on it, records accumulate in it, comparison relations are preserved across its updates, and the operational arguments of §§8, 10, 11 all turn on what the substrate can and cannot host as simultaneously committed content. The block as a totality is, by construction, operationally inert — that is the very feature the block defender refuses to give up by appealing to Option 3. So the choice between manifold and substrate is not between two equally posited structures; one has operational content the other lacks. VERSF earns its ontological status by the operational work the substrate does; the block on Option 3 declines to earn its ontological status at all and asks for it on credit. The asymmetry is precisely the point: a substrate that is operationally accessible at every chain-position is instantiated *by its activity*, whereas a block as a totality is instantiated by nothing, including the substrate's activity.

A sharper formulation closes the parallel rejoinder. The block defender's distinctive ontological commitment is *not* the sum of the slice-claims. Every slice may have its operational content fully accounted for chain-locally — VERSF grants those operational facts in full. The block defender's distinctive surplus claim is that all slices co-exist *as a totality* with simultaneous physical standing. This surplus claim is not entailed by the slice-claims: granting that each slice is operationally constituted does not underwrite the further claim that the slices have joint,

simultaneous, physical existence as a 4D object. The slices have, between them, only the relational structure that chain-locality already supplies; the totality is something additional, asserted beyond what the slices entail. And it is precisely this additional totality-claim that nothing instantiates. So when the eternalist says "VERSF and the block both posit a structure," the reply is: VERSF posits a structure (Λ, the substrate) whose elements are operationally constituted, with the structure inheriting operational content from the relata. The block defender posits a totality (the manifold-as-state-of-affairs) whose elements are operationally constituted *individually*, but whose totality-as-such is operationally constituted by nothing. The asymmetry is in the surplus.

The deeper deficit: explanatory idleness. The instantiation deficit is the structural problem with the block as a physical thesis; explanatory idleness is the corollary that makes the structural problem decisive. All explanatory work the block defender requires — accounting for observed correlations, regularities, dynamics, predictive successes — is already performed chain-locally. Every observation, every measurement, every regularity is mediated by local commitments and the chains relating them; nothing in physical practice has ever required appeal to the block-as-totality to explain or predict anything. The block defender's distinctive ontological commitment, the totality-claim, is therefore not merely uninstantiated. It is *explanatorily idle*. If you removed the totality-claim and kept only the chain-local facts, all of physics, all observed phenomena, all predictive regularities would remain accounted for. The totality is the only thing that depends on the totality; everything else depends on what the chains do.

This converts the instantiation problem into a *redundancy* problem. The block defender is asking us to accept an additional ontological commitment that does no explanatory work, on the grounds that it is mathematically describable. But mathematical describability is shared by infinitely many structures we do not regard as physically real. What ordinarily marks the difference between a description and a physical thesis is that the physical thesis does explanatory work the description alone does not. The block-as-totality does no such work. Stripped of its instantiation and stripped of its explanatory function, what remains is a mathematical structure plus the bare assertion that this mathematical structure is "real." That is mathematical realism with a label, not a physical thesis.

The "show me" test. The argument has a compressed conversational form that helps fix the dialectic. To the eternalist who says "all moments equally exist as a 4D physical totality": *show me*. Not the equations describing the totality. The totality itself. The physical thing, the state of affairs.

The eternalist will gesture at the manifold's mathematical description — but that is the description, not the totality. They will gesture at present consequences of past events — but those are chain-local facts. They will gesture at predictions for future events — but those are currently committed mathematics. They cannot point to anything in the world that corresponds to the totality-claim, because nothing in the world does. The totality is exactly the part of the eternalist's position that has no physical correspondent.

This is not verificationism. The demand is not for *empirical verification* but for *physical correspondent*. A claim about physical reality with no physical correspondent at all is not

unverified; it is uninstantiated. Verificationism would say that an unverifiable claim is meaningless; the present argument says that an uninstantiated claim is mathematical-realist rather than physical-realist, and the demand is on the content of "physical," not on the testability of the claim.

This is not a refutation, it is a revelation. The eternalist's distinctive ontological commitment is precisely the part of their view that fails the "show me" test — and "show me" is just what "physically real" demands.

The VERSF alternative does not face this problem. VERSF posits no 4D totality requiring instantiation. The substrate is lower-dimensional and local, updating along Λ. What appears as four-dimensional spacetime in our mathematical descriptions is *reconstructed* from accumulated records — a representation of what the substrate has done, not a higher-dimensional state of affairs that the substrate must somehow instantiate. Compare:

- *Block universe:* 4D totality exists first; present experience is an illusion within it. The totality requires an unexplained instantiation structure capable of hosting all temporal layers as physically simultaneous.
- *VERSF:* commitment interface updates first; 4D spacetime is a reconstruction from accumulated records. No 4D interface is required because no 4D totality is posited as physically real.

VERSF needs only what is operationally available anyway: local commitment, record accumulation, ordered reconstruction. The block universe, taken as physical realism rather than mathematical realism, requires substantially more structure than it can deliver.

Statement. The argument in its sharpest form:

A block universe cannot be physically real merely by being mathematically describable. To be physically real, it must be instantiated. But instantiating all temporal states simultaneously requires an accessibility structure with simultaneous access to all temporal layers. No physical process inside the universe possesses such access. Therefore the block universe, taken as physical realism rather than mathematical realism, requires an interface that nothing in the universe instantiates — and the burden falls on the block defender to specify what that interface is or to concede that the block is a representation rather than a state of affairs.

This does not refute the mathematical block; the four-dimensional manifold remains a valuable representation. What it refutes is the *ontological* block — the claim that all events equally exist as a four-dimensional physical totality. That claim, the argument shows, has no operational content the substrate can supply. The block universe does not eliminate becoming; it relocates physical instantiation into an unexplained four-dimensional totality.

13.3 Barbour's timeless physics

Barbour's earlier view in *The End of Time* eliminates time entirely, replacing it with an atemporal configuration space (Platonia) whose points are "Nows"; apparent succession is recovered from structural relations between Nows. His mature view in *The Janus Point* develops a more sophisticated programme based on shape dynamics, in which the fundamental physical content is conformal, scale-invariant shape rather than metric structure, and the arrow of time is recovered from a "shape complexity" measure that grows monotonically away from a unique low-complexity point — the Janus point — in both directions of what we ordinarily call time.

VERSF shares Barbour's scepticism of fundamental time and the substantivalist conception of space, but disagrees on three counts.

First, Barbour's atemporal totality — the set of all Nows in *End of Time*, or the shape space in *Janus Point* — reinstates exactly the kind of mathematical-as-physical reading that §13.2 contests. The question "is the totality of Nows (or shapes) physically instantiated as a whole?" generates the same trilemma: representation, unmotivated meta-interface, or verbal-only existence. The shape-dynamics formulation is more sophisticated mathematically than the original Platonia, but its ontological status faces the same operational pressure.

Second, the recovery of becoming from shape complexity is structurally similar to recovering temperature from disorder: it gives an arrow but not the underlying constitutive process. Why should complexity grow rather than fluctuate freely about its minimum? Barbour's answer ultimately rests on probabilistic arguments about typical paths through shape space. VERSF's commitment dynamics is meant to be the *constitutive* process — the substrate is genuinely committing structure that wasn't committed before, with monotonicity $\partial\rho/\partial\lambda \geq 0$ as a substrate property rather than as a measure-theoretic consequence on a pre-given configuration space.

Third, the commitment ordering is *intrinsic* in a stronger sense than Barbour's relational ordering: the configurations themselves come into being through commitment, rather than being eternal members of a configuration space from which a coherent succession is selected. Barbour's view is closer to a tenseless realism about shape, with becoming as a derived feature; VERSF is a substrate-first dynamicism in which becoming is the substrate's primary activity.

The two programmes are arguably closer than they appear, however. Both reject the four-dimensional manifold as ontologically fundamental; both build emergent temporal structure from a substructure that is in some sense atemporal at base. The substantive disagreement is on whether the substructure is best read as a configuration space (Barbour) or as an active substrate whose activity is commitment (VERSF). The VERSF case rests on the operational arguments of §§8, 10, 11: an atemporal totality has the 4D interface problem; an active commitment substrate does not.

13.4 The Page–Wootters mechanism

The original Page–Wootters mechanism recovers apparent evolution from entanglement between a clock subsystem and the rest of the universe in a globally stationary state. The mechanism inherits the static globality of the Wheeler–DeWitt picture: there is no fundamental dynamics;

what looks like time evolution from the system's perspective is a correlation between system and clock degrees of freedom in a timeless joint state.

The framework has been substantially refined in recent decades. Giovannetti, Lloyd, and Maccone have developed quantum versions that address some of the original difficulties — in particular, how clock measurements interact with the stationary state without breaking the symmetry, and how to reconstruct the Schrödinger and Heisenberg evolution from the conditional state of the system relative to the clock. The quantum reference frames literature — developed by Bartlett, Brukner, Vanrietvelde, and others — generalises the basic insight into a research programme in which different physical systems serve as reference frames for one another, with no preferred external frame, and time is one species of reference-frame structure among others. These more sophisticated formulations are explicit that "time" on this view is a *relational* structure between subsystems rather than an external parameter or an absolute coordinate.

VERSF differs from these refined views on the same fundamental point as from the original: the resource that generates evolution is not entanglement structure within a stationary global state but irreversible commitment on an active substrate. The Page–Wootters family is consistent with — even sympathetic to — the 4D interface problem of §13.2 in that it rejects a substantivalist time dimension. But it keeps a globally stationary state, which is itself subject to the instantiation question. In what sense is the globally stationary state of the universe physically instantiated, given that nothing inside the universe accesses it as a whole? The answer is again the §13.2 trilemma applied to the global state-vector. By contrast, VERSF posits no globally stationary anything: there is local commitment along chains through Λ, with the substrate's activity being what generates correlations rather than the correlations being a stationary backdrop. Becoming, on the VERSF reading, is operationally efficacious in a way the Page–Wootters becoming is not — the latter is, on its own terms, an appearance derived from a deeper timeless reality.

The two pictures may be compatible at the coarse-grained level. The clock subsystem in Page–Wootters could be reinterpreted as a record-rich coarse-graining of substrate activity, and the entanglement structure as the relational shape of records across chains through Λ. The foundational disagreement is on what does the constitutive work: a stationary state plus entanglement, or an active substrate plus commitment. VERSF's case is again the operational arguments of §§8, 10, 11.

A further weakness worth flagging. The Page–Wootters family inherits the spatial structure of whichever quantum theory is being conditioned on the clock, but the conditioning itself does not produce or explain that structure. Spatial dimensionality is, on this approach, a *free parameter* of the framework rather than something the framework accounts for. By contrast, VERSF's spatial dimensionality is *constructed*: §11's structural argument explains why substrate commitments must take interface form, and §12's reconstruction mechanism explains how bulk depth is generated from those interface commitments. The Page–Wootters approach is silent on the question §11 answers; it does not address why the underlying quantum theory should have the spatial structure it has, or why three-dimensional bulk content should emerge at all.

13.5 Summary

	Becoming real?	Time fundamental?	Source of order	Source of three-dimensionality
Block	No	Yes (as dimension)	Static manifold	Built into the manifold
Barbour	No	No	Relational config	Shape space / configuration
Page–Wootters	Apparent only	No	Entanglement	Free parameter; not accounted for
VERSF	**Yes**	No	Commitment events	**Reconstruction from records along chains**

A note on the last two columns. The other three views distinguish "source of order" from "source of three-dimensionality" because their frameworks distinguish them: ordering and spatial structure are independent posits. In VERSF specifically these two columns *collapse* — ordering (the partial order Λ generated by substrate commitments) and three-dimensionality (the bulk depth reconstructed from interface updates along chains through Λ) have the same source: substrate activity. The table presents them as separate columns only for comparative purposes; the paper's central thesis is that they are co-constituted.

VERSF is the position that takes becoming seriously without reinstating a flowing background dimension.

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14. Anticipated Objections

Objection 1: The block universe already has a B-series ordering. Why need commitment events? The block has an ordering along its temporal axis, but the ordering is *given*; the manifold is laid out in advance. The objection conflates "having an ordering" with "the ordering being generative". In VERSF, the ordering does generative work: each commitment event adds structure to ρ. The block has no analogue of this.

Objection 2: Isn't "operationally undefined" just epistemology dressed up as ontology? The object is still three-dimensional in itself. The objection assumes there is a substrate-independent ontological dimension distinct from operational content — sense (2) of §9.1 read as primitive. VERSF rejects that assumption explicitly. The frozen-reality conclusion is not "we cannot know the object's dimensionality"; it is that dimensionality has no fact-of-the-matter independent of the substrate processes that constitute it. The critic's "still 3D in itself" tracks mathematical dimension (sense 1), which survives trivially because it is a property of the representation. The substantive question — whether the object *is* three-dimensional in the world — has no answer except through what the substrate has committed, and in the frozen scenario the substrate has committed nothing further. The "in itself" to which the objection appeals is a posit of the container picture that VERSF gives up. This is a metaphysical commitment, not a definitional manoeuvre, and the paper stands or falls on it being defensible — which §9.1 argues that it is.

Objection 3: Doesn't this make 3D space mind-dependent? No. Commitment events are objective substrate processes; they occur whether or not anyone observes them. The argument is about what physicality consists of, not who is looking. A universe with substrate activity but no observers is fully three-dimensional in the operational sense; a universe with observers but no substrate activity is not.

Objection 4: The flip-book has an external flipper. Doesn't your account smuggle one in? The flip-book analogy is heuristic. In VERSF, there is no external flipper. The substrate's update is intrinsic; commitment is a property of the interface, not an action performed on it from outside. The "ordering" is a feature of the substrate, not a parameter we impose.

Objection 5: How is this falsifiable? The VERSF programme more broadly is constrained by its observational consequences (rotation-curve predictions, fine-structure derivation, perturbation spectra, etc.) The present paper is foundational and does not by itself generate new predictions. Its falsifiability is parasitic on the framework: if the master action's predictions fail, the present account fails with it. But the paper is not merely tidying up. It articulates the metaphysical commitment that the rest of the programme presupposes — most notably the identification of ontological with operational dimension in §9.1, and the instantiation-and-accessibility structure of physical reality in §10 — and it sharpens what the existing predictions are predictions *about*. The §13.2 trilemma against the ontological block is, if it goes through, a substantive contribution to the philosophy-of-physics literature in its own right; it does work, even if it does not generate fresh numbers.

Objection 6: How does the temporal accessibility argument cohere with special relativity, which rules out a preferred simultaneity? It coheres straightforwardly: the temporal accessibility argument is chain-local from the start, not a claim about a global preferred "now." Along any commitment chain through Λ, accessibility at any chain-position is confined to the locally committed slice plus its order-ideal of records and antichain of unrealised potentialities. Different observers — different chains through the same partial order — generate different patterns of accessibility, and this difference is exactly what the relativity of simultaneity expresses at the coarse-grained level. The argument doesn't require rescue from relativity; relativity is what one expects on the picture. The block view's claim that "all events equally exist" is unaffected by this: relativity tells us simultaneity is frame-dependent, not that some frame has access to all events at once. No chain does.

Objection 7: The temporal accessibility argument is just a limitation of observers dressed up as ontology. The argument is structural and causal, not perceptual. It applies identically to a universe with no observers whatsoever. The claim is not "observers cannot perceive all of spacetime at once" — that would indeed be psychology. The claim is that physical causation, considered as an objective substrate process, exposes only the locally committed slice along whichever chain through Λ the process belongs to, plus its records. A measurement apparatus, a planetary system, a galaxy, or any other physical system without consciousness is in exactly the same operational position: it interacts with present commitments and present records, not with past events or future events directly. The "limitation" is causality itself, not anyone's epistemic access. The block view's posit that "all events equally exist simultaneously" describes a state of

affairs that no physical process in the universe — observed or unobserved — can ever instantiate.

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15. Implications

If the picture developed here is correct, several consequences follow.

15.1 Time is emergent without being illusory. Temporal flow is not a primitive feature of the universe, but its emergence does not make it unreal. The accumulated ordering of commitment events is objective, structural, and physically efficacious — it just isn't a fundamental dimension.

15.2 Geometry and temporality are co-constituted. Experienced spatial depth and experienced temporal flow are both products of substrate activity. A frozen universe loses both at once; both depend on the same operational resource.

15.3 Physics shifts from static geometry to active reconstruction. The deepest physical description is not "particles inside spacetime" but "evolving substrate dynamics generating persistent structure". This is consistent with — and a natural foundational complement to — the master action programme of the VERSF corpus.

15.4 The "container" picture of spacetime is misplaced. Spacetime is not a container; it is a coarse-grained re-description of substrate activity. This dissolves several long-standing puzzles about why spacetime "exists" — there is no container to explain, only ongoing substrate updates whose coarse-graining we describe geometrically.

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16. Conclusion

We posed a simple question: if reality were completely frozen, would anything still meaningfully possess three-dimensional properties?

The VERSF answer is precise. **Three-dimensional geometry remains mathematically definable, but operational three-dimensionality requires ordered fact-updates.** Strip away the updates and you keep the configuration, but you lose the physicality. Many of the features we associate with the physical world — motion, causality, persistence, temporal order, comparison, experienced continuity — become operationally undefined.

What we have called "the flow of time" therefore emerges from the ordered progression of commitment updates rather than from time existing as a flowing background dimension. The universe does not fundamentally move through time. It continuously *reconstructs itself* through irreversible commitment events whose accumulated records constitute the experienced world.

The implication is not that 3D structure is unreal. It is that:

- geometry is real,
- persistence is real,
- structure is real,

but each of these is a coarse-grained property of substrate activity, not a static container in which substrate activity happens. The sensation of flowing time is what it feels like, from inside, to be a coarse-grained pattern in a substrate that continually commits.

The deepest physical fact about the world, on this account, is not that it *is*, but that it *commits*.

Companion papers in the VERSF programme develop the master action and unique record current (Taylor, VERSF Master Action paper), the monotonicity of ρ and admissibility closure (Taylor, Admissibility Closure paper), and the coarse-graining route from substrate activity to emergent geometry (Taylor, Constitutive–Predictive Bridge paper). The present paper supplies the foundational reading those technical results presuppose.

Appendix A: Derivation of the VERSF Architecture from a Single Principle

The main argument develops VERSF's claims as a connected sequence: distinction-ontology in §6.2, partial-order structure in §6.1, operational identification in §9.1, interface-likeness in §11, chain continuity in §12, anti-block in §13.2. The §11.5 methodological note acknowledges that these moves form a *package* rather than a strictly linear chain. This appendix takes the unification a step further. It shows that the entire package can be recovered as a structured consequence of a single foundational principle, with each VERSF claim emerging as a short derivation.

The derivations are not rigorous proofs. Each step involves conceptual unpacking of what the principle requires, and a critic could press at any step on the unpacking. What the appendix delivers is a demonstration that VERSF's claims hang together with unusual tightness: a reader who grants the foundation principle finds the rest of the framework following with relatively little additional commitment, and those who would reject VERSF must locate their objection at the level of the foundation principle rather than at the level of individual derivations.

A.1 The foundation principle

FP. Physical reality is constituted only through operationally coherent distinguishability.

Unpacking the three load-bearing terms:

- *Operationally*: there are processes that engage with the relevant facts — measurement, comparison, propagation, inheritance, record-formation.
- *Coherently*: the processes and their outputs maintain consistent relations across applications and across observers; the distinctions made by one operation are preserved under the comparisons of others.
- *Distinguishability*: the capacity to differentiate one fact from another via operationally coherent means; what cannot be operationally distinguished does not count as a separate fact.

These three terms are not atomic; their joint unpacking is exercised across the derivations below, and the package's robustness depends on a unified reading of all three. A reader who accepts FP under one unpacking (say, "operational" as bare measurement-availability) may decline to accept it under another (say, "operational" as full coherent comparison across substrate processes). The derivations that follow assume the unified reading; pressing the unpacking at any single derivation step generally also presses it for the principle as a whole.

FP has two halves. The *positive* half: physical reality is constituted *through* operationally coherent distinguishability — what *is* physically real is what such distinguishability brings into being. The *negative* half: physical reality is constituted *only* through this — nothing beyond what operational coherence supplies counts as physically real.

The rest of the appendix shows what follows.

A.2 Derivations

D1. Distinction is fundamental (§6.2). If physical reality is *constituted* through distinguishability, then distinctions are the basic constituents of physical reality. There are no things first, with distinctions drawn between them as an afterthought; what we call "things" are coarse-grained clusters of stable distinctions. This is §6.2's distinction-ontology: difference is fundamental; separate things are emergent.

D2. Operational = ontological (§9.1). If physical reality is constituted *only* through operationally coherent distinguishability, then there is no further fact about what an object *is* over and above what operational distinguishability constitutes. Ontological status is operational status. There is no "intrinsic being" hiding behind the operational facts because FP allows no "behind." The §9.1 identification — *ontological dimension is operational dimension* — is a direct corollary.

D3. Void / substrate identity (§6.2). Consider FP at the limit of no committed distinction. At this limit no distinguishability has been actualised — there is no physical reality in the actuated sense, only the capacity for distinguishability to be exercised. This capacity is the void: not absence, but unactivated potential. The same single reality, exercising distinguishability, is the substrate-in-action. Void and substrate are therefore the same thing in different states. The structural relationship between void and interface — *the interface is to the void what a surface is to a bulk* — falls out of D6 below: the interface is the locus where the substrate's

distinguishability is actually being exercised, while the void is the surrounding undifferentiated condition.

D4. Λ as partial order (§6.1). Operational coherence between two distinctions requires that they be operationally related, which in turn requires a causal pathway through which one's record content can constrain or be compared with the other's. Where such a pathway exists, the distinctions are causally ordered; where it does not, they are unordered. The collection of all commitment events with this ordering forms a partial order — Λ. Richer "container" readings of Λ (as a dimension, parameter, count) are ruled out by D2: they posit ontological facts beyond the operational ones.

D5. Antichains and quantum non-locality. From D4, spacelike-separated commitments are antichain elements of Λ — unordered with respect to each other. Given the empirical fact that Bell-type correlations between such commitments exist, FP requires these correlations to be operationally underwritten by something. Causal influence between antichain elements is ruled out by D4's structure. But two antichain elements may share common ancestors lower in Λ, and the joint record content of those ancestors can underwrite the correlations without invoking causal influence between the antichain elements themselves. Bell-type quantum correlations on this reading are correlations across antichain elements with shared ancestors — not causal influences but coherent correlations from common operational origins. The substrate-level expression of "no signalling but real correlation" follows from D4 and FP applied to the empirical correlations.

D6. Interface-likeness (§11). What can be *simultaneously* committed at a single position in Λ? FP requires that the simultaneously committed content be operationally coherently distinguishable as a single coherent commitment. Bulk-level distinctions — the interior structure of extended regions — cannot satisfy this requirement at a single Λ-position: their constitution requires traversal (sequential probing, layer-by-layer comparison), which by definition extends across multiple Λ-positions. Boundary-level distinctions, by contrast, are accessible without traversal; they can be given as a single coherent operational fact at one Λ-position. The substrate's simultaneously committed content is therefore confined to boundary-level: the interface. Bulk depth must be reconstructed across chains, never contained at a single Λ-position. This is §11's interface-likeness, derived directly from FP plus the coherence requirement.

The conditional structure of §11 ("conditional on substrate-first dynamicism") is recovered here as: D6 follows from FP through D2's negative-half application — there is no constitution-without-accessibility, so the simultaneous-commitment question becomes a question about what can be simultaneously *accessed* coherently. A tenseless framework dissolves the question by giving up D2; D6 follows for any framework that holds onto D2.

D7. Chain continuity (§12). Distinguishability over time requires that distinctions persist as the same distinctions — yesterday's commitment must be operationally identifiable as the commitment now under consideration today. Persistence in this sense requires *causal inheritance*: today's commitments must carry forward the record content of yesterday's, with comparison relations preserved. Discontinuous (non-inheriting) updates would mean today's commitments are operationally indistinguishable from fresh commitments unconnected to

yesterday, which would not preserve distinguishability over time. Chains through Λ with coherent causal inheritance are therefore necessary for operational temporal extent — exactly the §12 condition.

D8. Monotonicity (§12.6). A commitment, once made, cannot be un-made without leaving a trace; and if the trace is removed, the removal is itself a further commitment. The record field ρ therefore grows monotonically along any chain: $\partial\rho/\partial\lambda \geq 0$. The irreversibility of distinction follows from its operational status: to be a distinction *is* to have been operationally drawn, and operations leave operational consequences.

D9. Anti-block (§13.2). *The full development is in §13.2; D9 here summarises the structural shape and locates the anti-block conclusion within the FP-derivation.* The block universe's distinctive claim is that all moments equally exist as a four-dimensional physical totality. Apply FP. Is there an operationally coherent distinguishability between "the totality is physically real" and "the totality is a useful mathematical description"? Every operation testing the claim engages chain-locally; every record is a present structure; every prediction is currently committed mathematics. No operation distinguishes the totality-as-physically-real from the totality-as-mathematical-description. Therefore, by FP, the totality-claim is not part of physical reality. The §13.2 instantiation requirement is what FP looks like applied to the block defender's surplus claim; the §13.2 explanatory-idleness argument is what FP looks like applied to the question of whether the totality earns its ontological standing. The "show me" test of §13.2 is FP turned into a conversational gesture.

A.3 What the derivations deliver and what they do not

Each derivation involves judgment, particularly in the unpacking of *operationally coherent distinguishability*. A determined critic could press the unpacking at any step. The three places where pressure is most plausible are D3 — where the identification of void with substrate-in-action is best read as a minimal-cost interpretation of FP rather than a strict derivation, since FP itself is silent on what the unactivated capacity for distinguishability *is* — D6, where the constraint on simultaneous coherence licenses the interface-likeness conclusion via the traversal-requirement, and D9, where the operational test of the totality-claim presupposes FP's negative half ("only through"). The two latter positions VERSF defends in the main text (§11 and §13.2 respectively); D3's identification is a structural commitment of §6.2 that the appendix recovers as the most economical reading of FP-at-zero-commitment. The appendix locates these dialectical pressure points cleanly rather than dispersing them.

What the derivations *do* establish is the unusually tight coherence of VERSF's architecture under a single foundational principle. The package character noted in §11.5 here gains its structural anchor: every major claim is recoverable as a short consequence of FP. A reader who grants FP can run the derivations forward; a reader who does not finds the disagreement located at FP itself rather than at any single VERSF commitment. The dispute about VERSF's correctness is therefore the dispute about FP's correctness — and FP, as §9.1's constraint argument shows, is the principle that pays no surplus-structure cost.

A.4 The slogans of the main argument as derivation rest-points

The main argument's slogans reappear in the derivation as natural rest-points, each marking a step in the unfolding of FP:

- *Difference is fundamental; separate things are emergent* — D1, the constituents of physical reality.
- *Ontological dimension is operational dimension* — D2, the negative half of FP applied to objects.
- *Reality is in the chain, not in the slice* — D6 + D7, what simultaneity gives and what the chain reconstructs.
- *The substrate behaves interface-like because simultaneous physical accessibility structurally privileges boundary commitments* — D6, the central architectural fact.
- *Becoming is local; there is no preferred chain-independent totaliser* — D7 + D8 in their chain-local form.
- *The deepest fact about the world is not that it is, but that it commits* — D1 + D9, viewed as the contrast between operational constitution and posited totality.

A.5 Status of the appendix

This appendix is offered as a *synoptic* derivation, not a *rigorous* one. Each step admits closer formal scrutiny than the appendix supplies; turning the synoptic argument into formal theorems is a separate project — one of the natural directions for the VERSF programme's future mathematical development. What the appendix delivers now is the demonstration that the seemingly modular components of VERSF are facets of a single principle, recoverable from FP with relatively little additional commitment at each step. The architecture is not a list of independent claims that happen to support one another; it is the structured unfolding of what physical reality looks like under operational ontology. FP is the foundation; the rest of the framework is what FP supports when its three load-bearing terms are unpacked consistently.

Appendix B: Formalisation of Operational Distinguishability, Interface Commitment, and Chain Reconstruction

Appendix A presented a *synoptic* derivation of the VERSF architecture from a single foundational principle. The present appendix supplies the corresponding *minimal formal development* — a skeletal formal system comprising definitions, an axiom, and propositions with proof-sketches for the load-bearing concepts (the partial order Λ, operational distinguishability, records, operational dimension, the interface theorem, and chain reconstruction). It is more than a sketch but less than a complete mathematical treatment; the latter belongs to the VERSF programme's companion papers.

The formalisation is intentionally minimal. Each definition makes its concept precise enough to be examined under formal scrutiny without committing the framework to a particular detailed mathematical model. A fuller development belongs to the VERSF programme's companion

papers — the Constitutive–Predictive Bridge, the Admissibility Closure, the master action and unique record current papers — where the relevant structures are developed in their own right with the requisite mathematical apparatus. What this appendix delivers is the formal scaffolding sufficient to ground Appendix A's synoptic argument and to make Appendix A's pressure points (D3, D6, D9) accessible to formal scrutiny.

B.1 The partial order Λ

Definition B.1 (The partial order Λ). Let E denote the set of commitment events. The structure $\Lambda = (E, \preceq)$ is defined by the binary relation:

$a \preceq b \iff$ the record content of a is necessary for the commitment of b.

Λ is a partial order:

- *Reflexive*: $a \preceq a$ for all $a \in E$.
- *Antisymmetric*: $a \preceq b$ and $b \preceq a \Rightarrow a = b$. (Two distinct commitments cannot have mutually necessary record content; this is the substrate-level expression of irreversibility.)
- *Transitive*: $a \preceq b$ and $b \preceq c \Rightarrow a \preceq c$.

Λ is not in general a total order: there exist $a, b \in E$ with $a \not\preceq b$ and $b \not\preceq a$ (incomparable elements). The incomparability structure encodes locality.

B.2 Chains and antichains

Definition B.2 (Chain). A subset $C \subseteq E$ is a *chain* iff every pair of elements is comparable:

$\forall\, a, b \in C,\ a \preceq b \vee b \preceq a.$

Definition B.3 (Antichain). A subset $A \subseteq E$ is an *antichain* iff every pair of distinct elements is incomparable:

$\forall\, a, b \in A$ with $a \neq b,\ a \not\preceq b \wedge b \not\preceq a.$

Chains correspond to causally ordered sequences — the substrate-level structure underlying temporally extended processes along a single worldline. Antichains correspond to spacelike-separated commitments. The chain-antichain decomposition structures both relativity (via locally chosen chains corresponding to foliations) and quantum non-locality (via antichain elements with common ancestors lower in Λ, per Appendix A's D5).

B.3 Operational distinguishability

Let S be the state space of substrate-level facts. At each commitment event $e \in E$, let O_e denote the set of operations available — measurements, comparisons, propagations, inheritance maps, and other substrate processes by which facts engage with one another.

Definition B.4 (Operational distinguishability). Two facts x, y ∈ S are *operationally distinguishable at e* iff:

∃ $\mathcal{O}$ ∈ O_e: $\mathcal{O}$(x) ≠ $\mathcal{O}$(y).

Definition B.5 (Physical equivalence). Facts x, y ∈ S are *physically equivalent at e* iff they are not operationally distinguishable:

x ∼_phys y ⟺ ∀ $\mathcal{O}$ ∈ O_e, $\mathcal{O}$(x) = $\mathcal{O}$(y).

Physical equivalence is an equivalence relation on S relative to O_e. Facts in the same equivalence class are operationally indistinguishable; no operation at e separates them. By §9.1's identification, they are physically the same fact, full stop. No surplus structure distinguishes them.

B.4 The operational ontology axiom

Let Phys(x) abbreviate "x is a physical fact" in the sense of §9.1's identification.

Axiom B.6 (Operational ontology axiom; formal version of FP). For all x ∈ S:

Phys(x) ⇒ ∃ e ∈ E, ∃ y ∈ S: *x is operationally distinguishable from y at e*.

Equivalently (contrapositive, using the equivalence relation of Definition B.5): if x ∼_phys y for every e ∈ E and every y ∈ S, then ¬Phys(x).

In words: x is a physical fact only if some operation at some event distinguishes x from some other candidate fact; if x is operationally indistinguishable from every fact at every event, then x has no operational content and is not a physical fact.

The axiom formalises the surplus-structure critique. Any candidate physical fact that fails the existential condition fails to be in Phys *by the axiom*; the appeal to such facts is therefore either operationally redundant (the fact is identical to an operationally accessible one under ∼_phys) or operationally vacuous (the fact contributes nothing to Phys). This is the formal version of §9.1's argument.

B.5 Records and monotonicity

Definition B.7 (Record at event e). The *record content at e* is:

ρ_e = ⋃_{a ⪯ e} δ_a

where δ_a denotes the record contribution of commitment event a. (In a measure-theoretic treatment: ρ_e = ∑_{a ⪯ e} w_a δ_a with weights w_a tracking record magnitude. The set-theoretic form suffices for the structural argument.)

Proposition B.8 (Monotonicity). For $a \preceq b$:

$\rho_a \subseteq \rho_b$.

Proof. Suppose $c \in \rho_a$. Then $c \preceq a$. By transitivity (Definition B.1), $c \preceq b$. Therefore $c \in \rho_b$. ■

In scalar form (ρ parametrised along a chain by coordinate λ): $d\rho/d\lambda \geq 0$.

This is the formal version of §12.6's monotonicity. Record content along any chain is monotonically non-decreasing; commitment is irreversible.

B.6 Operational dimension

Definition B.9 (Fact-map). At event e with operationally accessible region R_e and state space S, the *fact-map* is:

$F_e: R_e \to S$,

assigning to each point $x \in R_e$ the substrate-level fact $F_e(x) \in S$ committed at that point.

Definition B.10 (Operational dimension). Provided comparison operations exist at e — i.e., there exist $C_{ab} \in O_e$ such that $C_{ab}(F_e(x_a), F_e(x_b))$ is defined for at least one pair $x_a, x_b \in R_e$ — the *operational dimension* at e is:

$D_{op}(e) = \mathrm{rank}(dF_e)$.

If O_e contains no comparison operations, $D_{op}(e)$ is *undefined* (not zero).

Frozen case. If $O_e = \emptyset$ (no operations at e — the substrate at e is inert), then $D_{op}(e)$ is undefined by Definition B.10. The mathematical sense (1) of dimension persists because R_e is still a subset of $\mathbb{R}^3$ as a coordinate description; the operational sense (3) and, by the §9.1 identification, the ontological sense (2) do not. This is the formal version of the frozen-reality argument.

B.7 The interface theorem

Let K_e denote the *simultaneously committed content at e* — the operational content of e taken as a single commitment without internal traversal.

For a region R in the substrate's coarse-grained spatial domain with boundary ∂R, call a fact F over R a *bulk fact* iff its constitution requires distinctions at interior points of R that themselves require sequential resolution through Λ; call F a *boundary fact* iff its constitution is satisfied without such interior traversal.

Proposition B.11 (Interface theorem). For all e ∈ E, simultaneously committed content is restricted to boundary facts:

$K_e \subseteq \partial R$.

Proof sketch. Suppose, for contradiction, that K_e contains a bulk fact B(F). By the definition of bulk, the constitution of B(F) requires a sequence of distinctions $a \prec b \prec c$ (where a, b, c ∈ E are commitments at interior points of R, with the indicated ordering in Λ). But a single event e ∈ E has no internal Λ-ordering: e is one element of E, and the sequence (a, b, c) is constituted by three distinct elements. Therefore e cannot contain ($a \prec b \prec c$) as substructure, and so cannot constitute B(F) at a single Λ-position. Contradiction. Therefore $B(F) \notin K_e$. By exclusion, $K_e \subseteq \partial R$. ■

This is the formal version of §11.1–§11.2's interface-likeness derivation. Simultaneous commitment at any Λ-position is restricted to boundary-level content; bulk depth must be reconstructed across chains.

B.8 Chain reconstruction

Definition B.12 (Bulk reconstruction along a chain). For a chain C ⊆ E, the *bulk content reconstructed along C* is:

$B_C = \bigcup_{e \in C} K_e$

subject to the *inheritance condition*: for adjacent $e \prec f$ in C, there exists an inheritance map $\Phi_{e \to f}$ such that:

$\Phi_{e \to f}(K_e) \cap K_f \neq \emptyset$.

The inheritance condition captures *coherent causal continuity*. The map $\Phi_{e \to f}$ preserves the structural relations among committed facts (comparison relations, identity-over-time, record dependencies) as the chain advances from e to f.

Status of bulk content along a chain.

- *Without inheritance* (Φ trivial or the intersection condition systematically fails): the chain reduces to a sequence of unrelated simultaneous-content sets K_e, and no coherent bulk content is reconstructed. This is the formal counterpart of §12.7's decoherent reality.
- *With coherent inheritance*: B_C is the *structured* union of interface commitments along C, with the inheritance maps Φ supplying the relational structure that turns the bare union into a coherent reconstruction.

This is the formal version of §12's chain continuity. Reality is not a slice K_e but a coherent chain (C, Φ).

B.9 Connection to Appendix A

The definitions and propositions above provide formal support for several of Appendix A's derivations:

- *D1, D2*: Definitions B.4–B.5 and Axiom B.6 formalise the operational ontology and the identification *ontological = operational*.
- *D4, D5*: Definitions B.1–B.3 provide the partial-order structure and antichain framework.
- *D6*: Proposition B.11 formalises the interface theorem.
- *D7*: Definition B.12 formalises chain reconstruction.
- *D8*: Proposition B.8 formalises monotonicity.

Other derivations in Appendix A involve commitments not fully captured by the present formalism. D3 (void/substrate identity) requires an interpretation of FP at zero commitment that is conceptual rather than mathematical; D9 (anti-block) requires the §13.2 dialectical machinery — instantiation deficit, explanatory idleness, the "show me" test — which is philosophical work rather than formal derivation. The appendix supports the synoptic argument without claiming to formalise it in full.

B.10 Status

This appendix is offered as a *minimal* formalisation, not a complete one. Each definition admits closer scrutiny. The most plausible places to press:

- *The state space S and the equivalence relation on it* (Definitions B.4–B.5). What structure does S carry — algebraic, topological, measure-theoretic? The present definitions leave S as a set; richer development would specify additional structure.
- *The set O_e of operations available at e*. What counts as an operation; what closure conditions O_e satisfies; how O_e relates across distinct events e, f ∈ E. These questions are addressed in the master action and Admissibility Closure papers.
- *The "bulk fact" predicate and the existence claim in Proposition B.11*. The proof-sketch presupposes a precise notion of "constitution requires sequential resolution through Λ" — making this fully rigorous requires the development of substrate-level constitution relations in their own right.
- *The inheritance maps Φ_{e→f}* in Definition B.12. Existence, uniqueness, composition properties (Φ_{e→g} = Φ_{f→g} ∘ Φ_{e→f}?) — all are non-trivial and would be developed in a fully rigorous treatment.

Each of these admits formal development beyond what the appendix supplies. The companion papers in the VERSF programme address some of this further development; others remain to be worked out as the programme matures.

What the appendix delivers is the minimal formal scaffolding sufficient to ground Appendix A's synoptic derivation and to make the framework's pressure points formally accessible. A reader who would press at D6's interface conclusion can do so against Proposition B.11; a reader who would press at the operational ontology axiom can do so against Axiom B.6. The formal scaffolding does not by itself force the philosophical conclusions of the main text; it makes the conclusions formally tractable.