The Foundational Architecture of the Void Energy–Regulated Space Framework (VERSF)

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For the General Reader

Why does time move forward? Why do measurements produce definite outcomes? Why does entropy always increase? These questions share a common root: the mystery of how irreversible facts arise in a physical world whose fundamental equations are perfectly reversible.

This paper proposes an answer. At the deepest level, physical reality is built from *distinguishability* — the capacity of physical states to be told apart. When a distinguishability relation becomes permanently recorded, it forms a *commitment event*: an irreversible physical fact. Time, on this view, is the ordered accumulation of such events. Entropy measures their cost. Physical law is the set of constraints that determines which events are permitted and at what rate.

The paper organizes this idea into five *foundational pillars*:

- **The Void** — the reversible substrate from which committed facts emerge
- **BCB** — the bookkeeping principle governing how many distinguishable records a region can sustain
- **TPB** — the rate at which those records form, bounded by quantum mechanics
- **Admissibility** — the constraints that determine which transitions may become facts
- **Time as Change** — the count of committed records, which is what a clock actually measures

Together these pillars form a unified map showing how spacetime structure, quantum behavior, and physical law all emerge from the dynamics of distinguishability and commitment. No exotic mathematics is required to follow the conceptual argument; the formal sections develop the precise statement for readers who want it.

Abstract

The Void Energy–Regulated Space Framework (VERSF) proposes that spacetime, physical law, and observable dynamics emerge from deeper constraints on information, change, and physical admissibility. While prior work has introduced individual components of this framework across multiple papers, the foundational structure underlying the theory has not yet been presented in unified form.

This paper identifies and formalizes five foundational pillars of the VERSF framework: **Time as Change**, **The Void Substrate**, **Bit Conservation and Balance (BCB)**, **Ticks Per Bit (TPB)**, and **Admissibility**. Each pillar is defined precisely, given a formal mathematical characterization, and its logical role within the overall architecture is clarified. The paper also states the five core invariants that must hold across the programme, provides a full programme dependency diagram, establishes a shared notation glossary, and separates the theory into three layers — physical substrate, informational constraints, and emergent physics — to prevent layer-mixing across the paper set. Special attention is paid to resolving dimensional consistency across the framework's rate equations and to grounding the admissibility predicate in a well-defined mathematical domain.

These principles are compared with related research in thermodynamics, quantum information theory, gravitational entropy, and emergent spacetime proposals. The framework yields concrete structural differences from causal set theory, loop quantum gravity, constructor theory, and Penrose's conformal cyclic cosmology, and generates framework predictions concerning quantum decoherence rates, entropy scaling in early cosmology, and discrete spacetime signatures. The decoherence scaling conjecture is introduced as a framework-motivated consequence of the commitment-rate architecture, though a full master-equation derivation remains outstanding.

By situating VERSF within the broader landscape of modern theoretical physics, this paper clarifies how the framework addresses a central open problem — the structural origin of irreversible physical facts in a universe governed by reversible laws — and advances ongoing discussions about the nature of time, entropy, information, and the emergence of physical law.

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1. Introduction

Modern physics rests on two extraordinarily successful frameworks: quantum mechanics and general relativity. Yet despite their predictive power, foundational questions remain unresolved. Among the most persistent are the nature of time, the origin of entropy, the emergence of classical reality from quantum systems, and the ultimate relationship between information and physical law.

A central unresolved issue underlying several of these questions is the origin of irreversible physical facts. The fundamental equations governing microscopic dynamics — including the Schrödinger equation, classical Hamiltonian mechanics, and the Einstein field equations — are time-reversal symmetric. Yet the observable world is not. Measurements produce definite outcomes, records accumulate, and entropy increases irreversibly. Explaining how irreversible facts arise within a framework built from reversible laws remains an open conceptual problem sometimes called the problem of fact production. Standard approaches either appeal to coarse-graining — treating irreversibility as an approximation — or invoke a collapse mechanism — treating it as a primitive addition to quantum mechanics. Neither provides a structural account of why irreversibility occurs or what constrains the rate and form of irreversible record formation.

The VERSF programme approaches this problem directly. It proposes that irreversible facts correspond to commitment events governed by structural constraints on finite distinguishability capacity. In this view, irreversibility is not added phenomenologically through coarse-graining but arises from the capacity structure of the physical substrate itself.

Over the past several decades, an increasing number of physicists have explored the possibility that physical reality may be fundamentally informational. The holographic principle ('t Hooft 1993; Susskind 1995), black hole entropy research (Bekenstein 1973; Hawking 1974), and quantum information approaches to gravity (Lloyd 2006; Bousso 2002) all suggest that information constraints play a central role in shaping physical law. Parallel developments — causal set theory (Bombelli et al. 1987), loop quantum gravity (Rovelli 2004), and constructor theory (Deutsch & Marletto 2015) — each attempt to derive spacetime or physical law from

more primitive discrete or informational structures, though each faces distinct foundational challenges.

The Void Energy–Regulated Space Framework (VERSF) builds on these developments by proposing that the observable universe emerges from a deeper operational structure governing how distinguishable physical records are formed and maintained. **Distinguishability is the deepest primitive of the framework, while the Void represents the reversible substrate in which distinguishability relations have not yet been irreversibly committed.** A bit is the irreversible commitment of a distinguishability relation — a stable record that two previously reversible states are no longer operationally equivalent. Rather than treating spacetime as the fundamental arena in which events occur, VERSF proposes that spacetime itself emerges from the dynamics of distinguishability, irreversible commitment, and finite distinguishability capacity within a reversible substrate. In the VERSF interpretation, quantum measurement corresponds to the transition of a reversible physical distinction into a committed record within the BCB capacity structure — connecting the measurement problem directly to the same commitment dynamics that underlie temporal emergence and entropy.

VERSF distinguishes itself from existing emergent spacetime proposals in four principal respects. First, it grounds temporal emergence directly in irreversibility rather than in a prior causal order (as in causal set theory) or a kinematic Hilbert space (as in loop quantum gravity). Second, it introduces a rate constraint — Ticks Per Bit — that reinterprets quantum speed limits as bounds on irreversible commitment throughput, yielding quantitative framework proposals absent from purely structural approaches. Third, it identifies a well-defined substrate — the Void — whose properties are operationally specified rather than posited geometrically, and whose mathematical structure is given explicitly as a measure space. Fourth, unlike Penrose's conformal cyclic cosmology (CCC), which grounds cosmological boundary conditions in entropy constraints but retains continuous geometry as primitive, VERSF aims to recover geometric structure from discrete informational commitments, treating the entropy-geometry relationship as a consequence rather than an input.

The framework also bears on a third recognized open problem: the deep origin of entropy bounds. The Bekenstein bound, holographic entropy scaling, and black hole thermodynamics all point to the existence of fundamental limits on the information content of bounded physical regions, but the structural reason those bounds exist remains debated. VERSF proposes that entropy bounds arise from finite distinguishability capacity — they are expressions of the BCB limit on how many irreversible records a region can simultaneously sustain — rather than being posited geometrically or derived from thermodynamic arguments alone.

In this sense the VERSF programme can be viewed as an attempt to address a longstanding question in theoretical physics: how irreversible physical facts arise in a universe whose underlying dynamical laws are reversible. The framework proposes that irreversibility is not a coarse-graining artifact but a structural consequence of finite distinguishability capacity and the commitment dynamics that operate within it. The narrative arc of the framework is therefore:

Reversible substrate → commitment events → irreversible facts → entropy → time → spacetime structure

Each arrow in that chain is governed by one or more of the five pillars developed in this paper.

To clarify the conceptual and mathematical architecture of this approach, this paper identifies and formalizes five foundational pillars. Section 2 states the five core programme invariants, provides the full programme dependency diagram, establishes a shared notation glossary, separates the theory into three layers, and introduces each pillar with a precise definition. Sections 3–7 develop each pillar in depth. Section 8 presents the integrated architecture and logical dependencies. Section 9 presents framework proposals and contrasts the framework with close competitors. Section 10 concludes. The goal of the present paper is therefore not to derive each component of the framework but to present the minimal architectural map that links them.

Scope of this paper. This paper is architectural and integrative. Its primary contribution is to identify the minimal dependency structure linking the existing VERSF strands — BCB, TPB, the Void, the fold papers, the law-closure programme, and the quantum foundations papers — into one coherent map. It is not the place where every derivation is completed, and it does not supersede the more detailed treatments in companion papers. Where a result is stated schematically here, the companion paper is the authoritative source. Readers should treat claims marked as proposals or provisional formalizations accordingly.

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2. Overview of the Five Pillars

2.0 The VERSF Programme Diagram *(paper-to-paper dependency map)*

The five pillars of this paper sit within the broader VERSF programme. The full dependency chain, from the physical substrate through to emergent physics, is:

```
       Reversible substrate (Void / pre-commitment layer)
                              |
                              ▼
              ┌─────────────────────────────────┐
              │        Fact-production layer     │
              │   (finite distinguishability +   │
              │     irreversible commitment)     │
              └─────────────────────────────────┘
                              |
                  ┌───────────┴───────────┐
                  ▼                       ▼
                BCB                      TPB
           capacity dynamics        rate constraint
                  └───────────┬───────────┘
                              ▼
                       Admissibility
                       (physical law)
                              |
                              ▼
          Emergent spacetime / QM / gauge structure
```
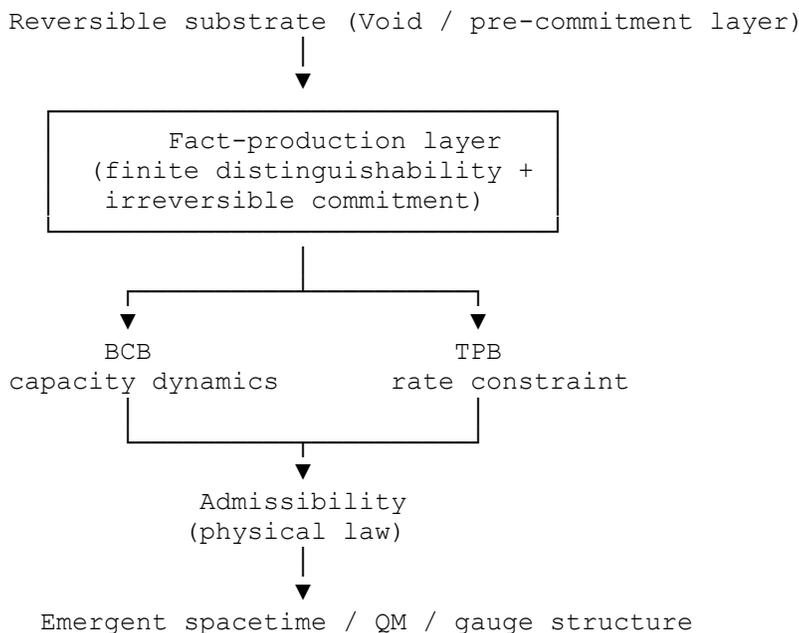
The programme diagram shows the broader conceptual development of the VERSF research programme, whereas the five-pillar structure below is the architectural compression adopted in this paper for purposes of unification. These are not the same dependency order: the diagram reflects the derivational sequence across the full paper set; the five pillars collapse that sequence into a minimal set of primitives for architectural clarity. Individual derivations of BCB dynamics, TPB rate constraints, admissibility structure, and fold geometry are developed in separate companion papers. The five-pillar structure introduced here should be understood as a unifying dependency map rather than a replacement for those detailed treatments. The top of the chain — reversible substrate through irreversible commitment — is collapsed here into the two primitives (Void + BCB) as a programme-level synthesis; the full derivation order is preserved in the individual papers.

By "fact-production layer" we mean the level at which finite distinguishability and irreversible commitment jointly determine which physical differences become stable facts. It is at this layer that the pre-commitment substrate's reversible dynamics become the committed records that constitute physical reality.

2.1 The Ontological Stack *(deepest conceptual ordering)*

Before stating the five core invariants, it is worth making explicit the ontological depth ordering that underlies the entire framework. Each level of the stack depends on — and is grounded by — the level beneath it.

Level 0 — Distinguishability *(deepest primitive)*
Physical states must support operational distinguishability relations. Formally: there exists an operational procedure that separates state A from state B. This is the primitive relational structure of the framework. Nothing more primitive is assumed. Distinguishability is not information — information is the stable record of distinguishability relations. What is fundamental is the relation itself.

Level 0.5 — Fold boundary *(structural interface)*
The transition from reversible distinguishability to irreversible commitment requires a structural interface. In the broader VERSF programme this is the fold boundary: the mechanism by which reversible distinguishability relations in the Void become stabilized as committed records. The fold is not a pillar — it is not a constraint principle but a structural transition. It answers the question of where commitment physically happens. The detailed geometry and dynamics of the fold are developed in the dedicated fold papers; at the architectural level of this paper, the fold is acknowledged as the substrate mechanism generating commitment events.

Level 1 — Commitment (bits)
A bit is what happens when a distinguishability relation becomes irreversibly recorded: a stable record that two previously reversible states are no longer operationally equivalent. Formally: *bit = committed distinguishability event = irreversible distinguishability record.* This ties the information-theoretic concept of a bit directly to the physical concept of a commitment event. Measurement, on this view, is not mysterious collapse — it is distinguishability becoming commitment.

Level 2 — BCB (capacity)

BCB becomes a conservation rule on committed distinguishability: the finite capacity of a region to sustain irreversible distinguishability records. This is why BCB leads naturally to entropy and holographic scaling — entropy is the density of committed distinguishability, and holographic bounds are the geometric ceiling on how many distinguishability commitments a bounded region can sustain.

Level 3 — TPB (rate)

TPB is the rate at which distinguishability becomes committed — the commitment throughput of distinguishability. This is why the Margolus–Levitin bound appears: it constrains how fast any physical process can convert reversible potential into irreversible committed records.

Level 4 — Time

Time becomes the ordered accumulation of committed distinguishability: τ = count of distinguishability commitments. This is the simplest possible definition of time that is consistent with irreversibility and well-defined far from equilibrium.

The full ontological stack is therefore:

```
Distinguishability          (Level 0 — deepest primitive)
        ↓
Fold boundary               (Level 0.5 — structural interface; Void →
commitment)
        ↓
Commitment / bits           (Level 1 — irreversible distinguishability record)
        ↓
BCB capacity                (Level 2 — conservation of committed
distinguishability)
        ↓
TPB rate                    (Level 3 — commitment throughput of
distinguishability)
        ↓
Admissibility               (Level 4 — constraint filter on commitments)
        ↓
Time τ                      (Level 5 — ordered accumulation of committed
distinguishability)
        ↓
Spacetime / QM / gauge      (Level 6 — emergent physics)
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One additional principle emerges from this stack that connects the pillars paper to the entropy paper:

The Distinguishability Cost Principle: The creation of new stable distinguishability relations requires physical expenditure of energy and capacity. Distinguishability cannot increase without cost.

This principle unifies four things at once: the Landauer cost of irreversible operations, the increase of entropy, the BCB capacity constraint, and the measurement process. The entropy paper and the pillars paper are two perspectives on the same principle: one describes the cost of commitment, the other describes the architecture within which commitment occurs.

2.2 The Five Core Invariants

Coherence across the VERSF programme requires that every paper respect five core invariants. These statements are backbone constraints; any result that contradicts them is inconsistent with the framework.

Invariant 1 — Finite Distinguishability *(from the FD papers)*
Any physically realizable system supports only a finite number of mutually distinguishable states.
This anchors BCB, the distinguishability barrier, and holographic scaling.

Invariant 2 — Irreversible Commitment *(from the fact-production papers)*
A physical fact corresponds to an irreversible commitment event.
This anchors time emergence, measurement, entropy growth, and the emergence of classical reality.

Invariant 3 — Reversible Substrate *(from the Void / fold papers)*
Physical commitments emerge from a reversible pre-commitment substrate.
This anchors the Void concept, reversible dynamics, and quantum evolution.

Invariant 4 — Finite Capacity *(from BCB)*
The distinguishability capacity of a bounded system is finite and dynamically balanced.
This anchors entropy, holographic scaling, and commitment bookkeeping.

Invariant 5 — Admissibility *(from the law-closure papers)*
Only transitions satisfying conservation, causal consistency, and capacity constraints may become committed records.
This anchors physical law, Hamiltonian evolution, and gauge structure.

These five invariants function as programme-level consistency conditions. The five pillars of this paper are the architectural expression of those conditions within a unified dependency map.

2.3 Notation and Glossary

The following terms and symbols are used consistently throughout this paper and are intended to align with their usage across the VERSF programme.

Term	Definition
Commitment	An irreversible record-forming transition by which a previously reversible distinction becomes stably represented in the committed layer
Microtick	A reversible update attempt within the pre-commitment layer; a candidate transition that has not yet passed the admissibility filter and has not yet become a committed record. Microticks are the raw substrate dynamics; they do not increment τ and do not consume BCB capacity
Distinguishability	Operational separability: two states are distinguishable if and only if there exists an admissible physical procedure that reliably discriminates them

Term	Definition
Void	The reversible pre-commitment layer; the substrate in which no persistent informational distinctions exist
BCB	The capacity bookkeeping principle governing the formation, balance, and dispersal of distinguishable records
TPB	The commitment rate per unit capacity; the conversion ratio at which the pre-commitment layer is drawn down into committed records
Admissibility	The constraint filter determining which transitions may become committed records

Symbol	Meaning	Units
τ	VERSF time — global dimensionless commitment count (ordering variable)	dimensionless
$\theta(x)$	Local coarse-grained conversion-depth field — spatially varying time-depth aggregate	dimensionless
t	Coordinate / clock time	s
$N(\tau)$	Number of committed records at VERSF time τ	dimensionless
N_BCB	Effective distinguishability capacity of a system or causal region	dimensionless
$\mathscr{R}(t)$	Total commitment rate	s^{-1}
$\mathscr{R}$_TPB	Commitment rate per unit capacity	s^{-1} per bit
Γ_form	Record formation rate	commitments per unit τ
Γ_disperse	Record dispersal rate	commitments per unit τ
$d\sigma_{irr}$	Differential count measure on irreversible commitment events	dimensionless

2.4 Three Layers of the Theory

The VERSF programme spans three distinct layers. The five pillars of this paper sit primarily in Layer 2, with Layer 1 providing the substrate and Layer 3 the downstream consequences.

Layer 1 — Physical substrate: The Void (reversible pre-commitment layer) and the reversible dynamics within it. This layer contains no committed distinctions and no emergent physics; it is the domain from which commitments are selected. Developed primarily in the Void and fold papers.

Layer 2 — Informational constraints: Finite distinguishability (FD), BCB capacity dynamics, TPB rate structure, and Admissibility conditions. This is where physical law is encoded as constraint structure on commitment. The present paper operates at this layer. Developed in the BCB, TPB, FD, and law-closure papers.

Layer 3 — Emergent physics: Spacetime geometry, quantum mechanical structure, and gauge symmetries, all understood as consequences of the constraint structure in Layer 2. Developed in the emergent spacetime, QM foundations, and gauge derivation papers.

Claims that mix layers — for instance, deriving spacetime geometry directly from the Void without passing through BCB and Admissibility — should be treated with caution as potentially skipping necessary intermediate structure.

2.5 Corpus Consistency Rules

The following rules govern usage across this paper and are intended as stable reference points for the broader VERSF paper set.

Deepest ontology vs architectural level. Finite distinguishability is ontologically prior in the DDF/canon layer. This paper compresses that deeper structure into Void + BCB as framework primitives for mapping purposes. Where this paper says "primitive," it means primitive within this architectural compression, not in the deepest programme ontology. *(Programme Rule A)*

Vocabulary: no unqualified "tick." The term "tick" is never used unqualified. Use: *microtick* for reversible pre-commitment update attempts; *commitment event* for irreversible record formation; *TPB rate* for commitment throughput per unit capacity. Many microticks may occur before one commitment event; each commitment event increments τ by one. *(Programme Rule B)*

Notation: τ is the global count only. τ denotes only the global dimensionless count of committed records (ordering variable). Local coarse-grained time-depth fields use $\theta(x)$. Emergent clock time uses t. These three must not be conflated. *(Programme Rule C)*

Layer rule. Substrate dynamics (Layer 1), informational constraints (Layer 2), and emergent physics (Layer 3) must not be mixed without an explicit derivational bridge. Claims that jump layers should be flagged as such.

2.6 The Five Pillars: Status Table

The ontological stack in Section 2.1 describes the deepest conceptual ordering of the framework, whereas the five-pillar scheme introduced here is an architectural compression used for programme mapping. These are complementary views of the same structure, not competing accounts.

Before developing each pillar individually, it is useful to state them together and indicate their logical relationships. The table below distinguishes *primitive* pillars — those taken as foundational without derivation from others — from *derived* pillars whose content follows from the primitives.

Pillar	Name	Core Claim	Status
I	Time as Change	Temporal progression = accumulation of irreversible commitments	Derived
II	The Void	Operationally defined substrate prior to committed distinctions	**Primitive**
III	Bit Conservation and Balance (BCB)	Finite capacity and dynamical balance governing distinguishable records	**Primitive**
IV	Ticks Per Bit (TPB)	Finite rate of irreversible commitment per unit informational capacity	Derived
V	Admissibility	Constraints determining which transitions may become committed records	Derived

Within the architectural compression adopted in this paper, the Void and BCB are treated as framework primitives. Both are taken as foundational postulates at this level: the Void is the assertion that a reversible substrate exists prior to committed reality; BCB is the assertion that the distinguishability capacity of that substrate is finite and governed by a conservation-and-balance principle. The logical chain of the derived pillars follows from these: TPB depends on BCB (a rate-per-capacity structure requires finite capacity); Admissibility depends on both the Void domain and the BCB/TPB bounds; and Time depends on the accumulation of admissible commitments. All remaining structure therefore follows from the two architectural primitives together with the standard apparatus of thermodynamics and quantum information theory.

Programme Rule A. In the deepest programme ontology, finite distinguishability is prior to the architectural primitives used in this paper. "Void" and "BCB" are treated as primitives only at the level of architectural compression. The two dependency levels are distinct and must not be conflated:

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Deep ontology (DDF/canon layer):
  distinguishability dynamics
        → reversible substrate / commitment boundary
        → capacity bookkeeping

Architectural compression (this paper):
  Void + BCB
        → TPB + Admissibility
        → Time + emergent physics
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The full DDF/canon explanation of why finite distinguishability is more primitive than Void+BCB is outside the scope of this paper; readers working from those papers should treat the architectural primitives here as compressions of that richer structure. This paper is a programme map, not a deepest-foundation replacement.

A compact formal definition used throughout: **a commitment is an irreversible record-forming transition by which a previously reversible distinction becomes stably represented in the committed layer.** Equivalently: **a bit is a committed distinguishability event** — an irreversible record that two previously reversible states are no longer operationally equivalent.

Commitments are the elementary events from which VERSF time is built and by which BCB capacity is occupied.

The logical dependencies are:

```
Void (II) + BCB (III) [Primitives]
                |
                |        ┌──→ TPB (IV) ──→ rate of capacity consumption
                |_____|
                └──→ Admissibility (V) ──→ filters allowed commitments
                          |
                          └──→ Time (I) = measure of accumulated commitments
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Relation to the Broader VERSF Paper Set

This paper integrates, rather than replaces, the companion BCB, TPB, fold, and law-closure papers. Those papers remain authoritative on their respective detailed treatments; the five-pillar structure here is an architectural compression of their content into a unified dependency map. The full explanation of what that compression entails — and what it does not claim — is in Section 2.6. Programme coherence across all papers is governed by the five core invariants in Section 2.2 and the corpus consistency rules in Section 2.5.

The detailed derivations supporting the quantum-mechanical layer of the framework appear in dedicated companion papers. The Double Square Rule establishes the Born rule from informational geometry. Physical Necessity of Quantum Probability Structure eliminates alternative probability laws. Complex Hilbert Space from Distinguishability Principles derives the quantum state space from the same distinguishability constraints that ground BCB. Quantum Measurement as a Tick Race provides a detector-level mechanism for outcome selection, connecting measurement directly to the commitment-event structure developed here. Together these papers constitute the quantum foundations strand of the programme; the present paper provides the architectural map within which their results are located.

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3. Pillar I: Time as a Measure of Change

3.1 Definition and Motivation

In VERSF, time is not treated as a fundamental dimension of spacetime. Instead, time is defined operationally as the accumulated measure of irreversible distinctions committed within a physical system. VERSF time is not an independent background parameter but an order parameter induced by admissible irreversible record formation.

This perspective aligns with and extends several established approaches. Barbour (1999) argued that time may be understood as a measure of change within configuration space. Rovelli (2018) emphasized the relational and thermodynamic aspects of time, demonstrating that thermal time — defined via the modular Hamiltonian of a KMS state — recovers the phenomenological flow

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of time in equilibrium statistical mechanics. In thermodynamics, the arrow of time is associated with entropy increase, suggesting that temporal directionality is a consequence of irreversible processes rather than a primitive spacetime feature.

VERSF goes further: rather than identifying time *with* entropy (which would make time ill-defined in non-equilibrium systems), time is identified with the *count* of irreversible commitment events, which is well-defined even far from equilibrium.

The treatment of time in this paper is the bookkeeping account: τ measures the accumulated count of admissible commitments. The fold papers in the broader VERSF programme address the structural origin of commitment events themselves — why the commitment boundary forms, what governs its geometry, and how causal order emerges from the fold structure. These are complementary treatments, not competing ones. The present paper takes the existence of commitment events as given and asks what temporal structure their accumulation produces; the fold papers ask what physical mechanism generates those events in the first place.

The canon distinguishes three temporal notions that must not be conflated:

$\boldsymbol{\tau}$ = global irreversible ordering variable (count of committed records)
$\boldsymbol{\theta(x)}$ = local coarse-grained conversion-depth field
$\mathbf{t}$ = emergent coordinate / clock time

Only τ is fundamental to the bookkeeping architecture developed here. **(i)** τ supplies the irreversible ordering of physical facts and is the primary VERSF time parameter throughout this paper. **(ii)** $\theta(x)$ is a coarse-grained field encoding the local depth of commitment conversion within the pre-commitment substrate. In some parts of the programme this quantity is related to TPB-style throughput measures derived from local commitment rates. **(iii)** t is the emergent coordinate time read off physical clocks, a coarse-grained aggregate that recovers standard relativistic proper time in the appropriate limit. Confusing these three — treating τ as a clock time, or treating $\theta(x)$ as a counting variable — produces the most common inconsistencies across the paper set.

Programme Rule C. The symbol τ is reserved for the global dimensionless count of committed records. Any local coarse-grained descendant quantity must use a different symbol. In this paper, the field-valued local time-depth is denoted $\boldsymbol{\theta(x)}$ — a spatially varying coarse-grained measure of local conversion efficiency derived from local commitment rates. $\theta(x)$ is a descendant of τ at the emergent coordinate layer; it is not the same object and must not be substituted for τ in bookkeeping expressions.

3.2 Formal Characterization

Let $\Sigma(\tau)$ denote the *set* of committed physical records at VERSF time τ, and let $N(\tau) = |\Sigma(\tau)|$ denote their count. A **commitment event** occurs when a physical distinction transitions from reversible to irreversible status. Define the VERSF time coordinate as:

$$\tau = \int_0^T d\sigma_{irr}$$

where $d\sigma_{irr}$ denotes the differential count measure on irreversible commitment events; when coarse-grained thermodynamically, it is proportional to irreversible entropy production. The coordinate τ is not presupposed but derived from this accumulation; it is measured in units of committed distinctions (dimensionless).

The rate of temporal progression with respect to an external coordinate t is:

$$d\tau/dt = \dot{N}\_comm(t)$$

where $\dot{N}\_comm(t)$ is the commitment rate at coordinate time t. In the limit of continuous commitment, τ recovers standard thermodynamic time up to proportionality; in discrete regimes, τ is step-valued and naturally produces quantized temporal structure with minimum step $\Delta\tau\_min = 1$ (one commitment event).

It is important to distinguish two kinds of discrete events that appear in the programme. **Microticks** are reversible update attempts within the pre-commitment layer — raw substrate dynamics that cycle through candidate configurations without generating stable records. They do not increment τ, do not consume BCB capacity, and are not observable as physical facts. **Committed records** (registered bits) are the subset of those attempts that pass the admissibility filter and become irreversible. Only committed records increment τ and consume capacity. The TPB rate $\mathscr{R}\_TPB$ measures the ratio of committed records to available capacity, not the rate of microtick cycling. This distinction is developed in the canon and Lorentz-emergence papers; it is essential for correctly interpreting the VERSF temporal structure: time advances by committed records, not by microticks.

Programme Rule B. The unqualified term "tick" is not used in this paper. Use only: **microtick** for reversible pre-commitment update attempts; **commitment event** for irreversible record formation; **TPB rate** for commitment-per-capacity throughput. Many microticks may occur before one commitment event; each commitment event increments τ by one; the TPB rate measures how many commitment events occur per unit of available capacity.

A note on corpus-wide terminology: some papers in the VERSF corpus — particularly the field-equations paper — use "tick" to mean an irreversible state update carrying fixed action, and "bit" to mean a stable configuration requiring many such ticks. That usage differs from the canon's microtick/registered-bit distinction adopted here. This paper sides with the canon resolution. Readers encountering "tick" in other corpus papers should check which convention that paper is using before importing it into this framework.

3.3 Relationship to Entropy and the Arrow of Time

Since irreversible commitment corresponds to entropy production, the framework entails:

$$d\tau \propto dS_{irr} \geq 0$$

This inequality follows from the definition of commitment: a distinction is committed precisely when it cannot be reversed without thermodynamic cost. The second law of thermodynamics is therefore encoded in the temporal structure of the framework.

It is important to be precise about what is and is not explained here. The *asymmetry* of τ — the fact that it is monotonically non-decreasing — follows directly from the definition of commitment. The *statistical tendency* of physical systems to increase entropy production is a separate question, addressed through BCB dynamics (Section 5). Within VERSF, temporal asymmetry is proposed to be grounded in the accumulation and dispersal structure of committed distinctions under BCB, rather than imposed as a separate postulate.

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4. Pillar II: The Void

4.1 Definition and Motivation

The second pillar — and the first of the two primitives — is the concept of the Void: the reversible substrate that constitutes the pre-commitment layer of physical reality. In the language continuous with the broader VERSF programme, the Void is the domain of physical activity that has not yet crossed the commitment boundary — the layer in which distinctions may form and dissolve without generating stable, irreversible records. The Void is defined by what it does not yet contain: committed distinctions.

This framing is continuous with how the reversible substrate appears in the BCB and TPB companion papers. In those treatments, the pre-commitment layer functions as the site of reversible dynamics from which committed records are selected; the present paper gives that layer a name and makes its structural properties explicit. The Void is not introduced here as a new entity but as a formalization of a concept already operative in the earlier programme.

The Void should not be confused with empty space or the quantum vacuum. In quantum field theory, the vacuum contains fluctuating fields and measurable energy density, with observable consequences (Casimir effect, Lamb shift). In contrast, the Void represents the baseline condition of uncommitted potential prior to the formation of stable physical records. It is not a field-theoretic state but an operational characterization of the pre-commitment layer.

Conceptually, this idea parallels Wheeler's notion of "pregeometry" and resonates with causal set theory's derivation of spacetime order from discrete relations. However, both Wheeler's pregeometry and causal set theory presuppose a background causal structure or combinatorial relation. The VERSF Void is more primitive: it is characterized entirely by the *absence* of committed distinctions, not by any pre-existing relational structure.

The deeper characterization of the Void — as the domain in which no persistent informational distinctions exist — is developed in the fold papers of the broader VERSF programme. There, the Void is the substrate from which the fold boundary emerges as the first structural asymmetry, and the zero-distinction condition is the starting axiom from which fold geometry and

commitment are derived. The measure-space encoding introduced in Section 4.2 is a provisional mathematical representation of that zero-distinction substrate for the purposes of this paper; the fold papers remain the authoritative treatment of its deeper structure.

Distinguishability at the deepest ontological level refers to the potential for operational separation between states, not to the existence of committed records. The Void therefore contains reversible distinguishability relations that have not yet been irreversibly recorded. This is the precise sense in which the Void is distinguishability-capable but commitment-free: potential separation exists, but no stable record of that separation has been formed.

In the broader VERSF programme, the transition from reversible Void dynamics to irreversible commitment events is associated with the emergence of a fold boundary. The fold represents the structural interface at which reversible distinguishability relations become stabilized as committed records — it is the mechanism that generates commitment events from Void activity. The detailed geometry and dynamics of this fold structure are developed in the dedicated fold papers. In the present architectural treatment, the existence of commitment events is taken as given, and the fold mechanism should therefore be understood as the deeper substrate process generating those events. The fold is not a pillar of the architectural framework — it is not a constraint principle but a structural transition — and it is not superseded by this paper's treatment of the Void.

4.2 Mathematical Structure

A measure space is the minimal mathematical structure capable of representing reversible configuration volume and supporting capacity bookkeeping without presupposing metric geometry or causal order. It is adopted here as the minimal structure sufficient to make capacity and reversibility mathematically precise: less structure would not permit capacity to be defined; more structure would import geometric or causal assumptions that VERSF aims to derive rather than assume. This is a formalization of what the companion papers treat operationally as the reversible substrate: it gives that substrate enough structure to make capacity and reversibility precise, without importing geometry. The Void $\mathcal{V}$ is formally a **measure space** $(\mathcal{V}, \mathscr{F}, \mu)$, where $\mathscr{F}$ is a σ-algebra of reversible configurations and μ is a reversibility measure. The measure μ should not be interpreted as spacetime volume; it represents reversible configuration measure in the pre-commitment substrate and therefore precedes spacetime geometry rather than being defined on it. The Void carries finite reversible potential; BCB formalizes the capacity constraint governing how much of that potential may exist as distinguishable commitment.

The pre-commitment layer is characterized by three conditions:

1. **Zero committed entropy:** $S\_comm(\mathcal{V}) = 0$
2. **Full reversibility:** For all processes P within $\mathcal{V}$, there exists a reverse process P^{-1} such that $P^{-1} \circ P = id\_\mathcal{V}$
3. **Finite capacity:** $\mu(\mathcal{V}) < \infty$ — the total reversible configuration measure is finite; $\mu(\mathcal{V})$ provides the reversible configuration measure from which the effective commitment capacity N_BCB is determined once energetic and geometric constraints are specified. The relationship between $\mu(\mathcal{V})$ and the realized commitment capacity therefore depends

on the physical conditions of the system and is developed in the companion BCB papers. The two quantities are not assumed identical at the coarse-grained bookkeeping level.

Here $\mu(\mathcal{V})$ denotes the finite reversible configuration measure of the substrate. N_BCB denotes the effective capacity for committed distinguishability records. In the present architectural treatment these are identified at the level of coarse-grained bookkeeping, but a full substrate-to-commitment derivation may distinguish them — the reversible configuration space and the capacity available for irreversible records are not obviously the same object at a fine-grained level.

The third condition is not derived from BCB in a circular manner. At the architectural level of the present paper, N_BCB is treated as a primitive capacity parameter. In the broader VERSF programme, its realised value in any physical system is expected to be constrained by energetic and geometric conditions, as developed in the companion BCB papers. The Void's finite capacity is a postulate at this level; BCB formalizes why that capacity takes the value it does in a system of given energy and geometry.

The operational content of the Void — a reversible pre-commitment substrate with finite capacity and no persistent distinctions — is stable across the programme. The specific measure-space formalization adopted here is provisional and should be read as a minimal mathematical placeholder rather than a completed ontology.

It is important to distinguish clearly between the Void's reversible configuration measure and the BCB distinguishability capacity. The Void condition $\mu(\mathcal{V}) < \infty$ states that the reversible substrate possesses finite configuration measure — a property of the reversible domain itself. BCB, by contrast, governs the number of irreversible distinguishability records that may coexist within that substrate. The two quantities therefore refer to different layers of the framework: $\mu(\mathcal{V})$ characterizes the reversible configuration space of the substrate, while N_BCB characterizes the bookkeeping constraint on committed distinguishability within that substrate. In other words, the Void specifies the size of the reversible phase space, whereas BCB governs the capacity of the irreversible record layer that emerges from it.

4.3 Operational Roles

The Void — equivalently, the reversible pre-commitment layer — serves four structural roles within VERSF:

- It provides the substrate within which reversible physical dynamics operate before commitment
- It defines the domain from which commitments are selected: every commitment event draws from the reversible potential held in the Void
- It sets the zero point from which temporal progression (Pillar I) and entropy accumulation are measured
- It defines the domain over which the Admissibility predicate (Pillar V) acts

5. Pillar III: Bit Conservation and Balance (BCB)

5.1 Definition and Motivation

The Bit Conservation and Balance principle — the second primitive pillar — is not merely an upper bound on information content; it is the dynamical bookkeeping principle governing the formation, maintenance, redistribution, and dispersal of distinguishable records within a finite substrate. What is conserved in BCB is the *capacity accounting* — the total budget of simultaneously sustainable distinguishable records — not the permanent existence of any particular distinction. Records form, are maintained at thermodynamic cost, and disperse when that cost can no longer be met; the budget that governs all three phases is what BCB tracks. BCB states that this capacity is finite and that the formation of new committed distinctions must remain balanced against its total. Finite distinguishability is also what prevents irreversible structure from being absorbed into an undifferentiated reversible substrate: it is what makes the emergence of a commitment boundary — separating Void from committed reality — structurally motivated rather than contingent. The value of N_BCB is not universal; it depends on the energy and bounding geometry of the system considered.

N_BCB denotes effective distinguishability capacity for a system or causal region under its energetic and geometric constraints: the maximum number of simultaneously sustainable distinguishable records that region can support. In practice N_BCB functions as a system-dependent capacity bound rather than a universal constant, with the cosmological horizon providing the largest known realization. It is not a naïve count of digital bits, not a single universal constant of nature, and not the same quantity at all scales. For cosmological causal patches, the geometric ceiling on distinguishability aligns with the holographic ceiling, while the realised dynamical history and current operational access may lie substantially below it — a distinction developed further in the VERSF distinguishability-hierarchy papers.

This principle resonates with several established results. The Bekenstein bound (Bekenstein 1981) places an upper limit on the information content of a bounded region:

$$S \leq (2\pi\, k_B\, R\, E) / (\hbar c)$$

The holographic principle further implies that distinguishability within physical systems is naturally expected to scale with the surface area of bounding geometry rather than its volume. VERSF is consistent with holographic area scaling and provides an interpretive route by which finite distinguishability capacity is naturally expected to scale with bounding area. In the VERSF interpretation this boundary scaling arises naturally because commitments correspond to the formation of separations between reversible and committed regions, which appear geometrically as boundary structures rather than volumetric degrees of freedom. This motivates the proposal that N_BCB scales approximately as $A / (4\ell_P^2)$ under the assumption that distinguishability commitments accumulate on boundary structures separating reversible and committed domains. The framework aims to motivate and eventually recover the Bekenstein–Hawking bound from BCB dynamics rather than assume it as primary; the more complete argument is developed in companion papers.

5.2 Formal Characterization

Let $N(\tau)$ denote the number of committed distinguishable records at VERSF time τ, and let N_BCB denote the BCB capacity. In practice, N_BCB should be understood as scale-relative effective capacity: a system-level or region-level distinguishability bound determined by its available energy and bounding structure, not a single universal constant of nature. The BCB principle asserts:

$N(\tau) \leq$ N_BCB for all τ

The dynamics of commitment are governed by:

$dN(\tau) / d\tau = \Gamma\_form - \Gamma\_disperse$

where Γ_form (commitments per unit τ) is the rate at which reversible Void configurations become irreversible records, and $\Gamma\_disperse$ (commitments per unit τ) is the rate at which existing records become thermodynamically indistinguishable and return distinguishability capacity to the Void. Both rates are dimensionless per unit VERSF time, since τ itself counts commitments. In statistical equilibrium, $\Gamma\_form = \Gamma\_disperse$ and $N(\tau)$ is stationary.

The BCB capacity is naturally expected to satisfy:

N_BCB $\sim A / (4\ell\_P^2)$

where A is the relevant bounding area and ℓ_P is the Planck length. Since each committed distinction requires a minimum thermodynamic cost of $k\_BT \ln 2$ to maintain, and since the maximum energy available within a bounded region is bounded by the Bekenstein constraint, the maximum number of simultaneously maintainable distinctions is argued to scale as $A / (4\ell\_P^2)$ in the Planck-energy limit. VERSF interprets holographic area scaling as the natural geometric expression of BCB-limited distinguishability capacity, and aims to recover the bound from BCB dynamics rather than assume it as primary. More precisely: this motivates the proposal that N_BCB $\lesssim A / (4\ell\_P^2)$ under the additivity assumption on distinguishability costs, rather than constituting a completed derivation.

5.3 Entropy as Informational Cost

Entropy, in the BCB framing, measures the informational cost and dispersal structure associated with maintaining distinguishable records within finite capacity. When records disperse — when distinctions become thermodynamically unresolvable — informational capacity is restored to the Void substrate. Within VERSF, the second law is interpreted as emerging from the combinatorics of finite distinguishability capacity: states that disperse commitments and restore usable capacity dominate the admissible state space. Entropy increase is thereby a consequence of BCB dynamics rather than an independent axiom. This is the BCB expression of the Distinguishability Cost Principle stated in Section 2.1: distinguishability cannot increase without physical cost, and entropy measures the accumulated cost of the distinguishability commitments a system has sustained.

6. Pillar IV: Ticks Per Bit (TPB)

6.1 Definition and Motivation

TPB presupposes BCB: without finite distinguishability capacity, a rate-per-capacity structure has no denominator and no meaning.

The primary content of TPB is a **commitment bookkeeping structure**: it tracks how rapidly irreversible distinctions are being formed relative to the total available capacity. This is a conversion relationship — a way of expressing the rate at which the reversible pre-commitment layer is being drawn down into committed records per unit of that layer's capacity. In the original TPB wording, the term "tick" was used for the irreversible commitment step; in this paper that usage is replaced by *commitment event* to avoid corpus ambiguity (Programme Rule B). Each commitment event occupies one unit of the distinguishability capacity counted by N_BCB, until that capacity is later restored through record dispersal.

This conversion structure is what makes TPB distinctively a VERSF concept rather than a restatement of existing quantum limits. It is a bookkeeping law for the commitment boundary: how fast is the pre-commitment layer converting into committed record, measured against how much capacity remains to do so.

The quantum speed limits enter secondarily, as physical constraints on how high that conversion rate can ever be. The Margolus–Levitin theorem (Margolus & Levitin 1998) establishes that a quantum system with average energy E can perform at most $2E / (\pi\hbar)$ state transitions per second, setting a ceiling on the rate at which any physical process — including commitment — can proceed. Landauer's principle (Landauer 1961) establishes the thermodynamic cost of each irreversible step. Together these place an energy-dependent upper bound on the TPB conversion rate, but they do not define it: the bookkeeping structure exists independently of what value that bound takes.

TPB does not identify all unitary state evolution with commitment. Standard quantum speed limits bound total physical turnover; the TPB conversion rate is restricted to the irreversible subset of transitions that form stable commitment records. The ceiling is inherited from quantum mechanics; the concept belongs to the commitment architecture.

6.2 Formal Characterization and Notation

The following notation is used consistently throughout this section:

- $\mathscr{R}(t)$**:** total commitment rate, commitments per second [s⁻¹]
- $\mathscr{R}$**_TPB:** commitment rate per unit capacity, per second per capacity unit [s⁻¹ per bit]
- $d\tau/dt = \mathscr{R}(t)$**:** emergent VERSF time accumulation rate

By the Margolus–Levitin theorem, the maximum physical transition rate is bounded by available energy. Margolus–Levitin bounds total physical turnover; TPB applies that ceiling specifically to irreversible commitment throughput:

$$\mathscr{R}(t) \leq 2E\_avail / (\pi\hbar)\ [s^{-1}]$$

The Ticks Per Bit rate $\mathscr{R}\_TPB$ normalizes this by the BCB capacity, yielding the commitment rate *per available capacity unit*:

$$\mathscr{R}\_TPB \equiv \mathscr{R} / N\_BCB \leq 2E\_avail / (\pi\hbar \cdot N\_BCB)\ [s^{-1}\text{ per bit}]$$

Here N_BCB is a dimensionless effective capacity count, so $\mathscr{R}\_TPB$ carries units of s^{-1}. The maximum:

$$\mathscr{R}\_TPB^{max} = 2E\_avail / (\pi\hbar \cdot N\_BCB)$$

is saturated in maximally entropic systems (black holes, thermal equilibria) and is far below saturation in low-entropy, highly ordered systems such as crystalline matter or quantum ground states. Most physical systems operate far below the TPB ceiling; TPB defines an admissible upper bound, not a typical realised rate.

6.3 Dimensional Consistency and Relationship to VERSF Time

The relationship between VERSF time τ (dimensionless commitment count) and coordinate time t (seconds) is:

$$d\tau/dt = \mathscr{R}(t) \leq 2E\_avail / (\pi\hbar)\ [s^{-1}]$$

Dimensional check: τ is dimensionless, t is in seconds, $d\tau/dt$ is s^{-1} — bounded from above by the Margolus–Levitin limit applied to the total system energy. Time passes fastest when available energy is highest and BCB capacity is near saturation. In regions where free energy is depleted, $\mathscr{R}(t) \to 0$ and VERSF time effectively freezes. This generates the framework proposals of Section 9.

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7. Pillar V: Admissibility

7.1 Definition and Motivation

The fifth pillar concerns Admissibility: the constraint structure determining which reversible Void processes may transition into committed physical records. Admissibility appears at two levels: a microscopic transition filter (conditions C1–C4 below) governing which individual commitment events are permitted, and a macroscopic closure condition on the stable committed algebra, governing which variable structures can persist as physical law. Admissibility is the

point at which the primitive substrate constraints become law-like selection rules on actualized commitments.

The mathematical domain of Admissibility is well-defined: a commitment map $\mathcal{T}$ is a measurable function from the Void measure space $(\mathcal{V}, \mathcal{F}, \mu)$ to the committed record space $(\Sigma, \mathcal{G})$, where $\mathcal{G}$ is a σ-algebra of distinguishable record configurations. Admissibility is a predicate on the set of all such measurable maps.

7.2 Formal Characterization

At the present stage, $\mathcal{A}(\mathcal{T})$ is a formal framework predicate collecting the necessary selection conditions on commitment maps; its operator-algebraic completion is deferred to future work. Let $\mathcal{T}: \mathcal{V} \to \Sigma$ denote a commitment map. The Admissibility predicate $\mathcal{A}$ is:

$\mathcal{A}(\mathcal{T}) = 1 \Longleftrightarrow \mathcal{T}$ satisfies conditions (C1)–(C4)

For a transition to be admissible, four conditions must hold:

- **(C1) Conservation:** All relevant conserved quantities (energy, momentum, charge) are preserved across the commitment. If Q is a conserved observable, then $\langle Q \rangle\_\Sigma' = \langle Q \rangle\_\mathcal{V}$ for all admissible $\mathcal{T}$.
- **(C2) Causal consistency:** The commitment does not generate closed causal loops within the committed record structure. The partial order induced on Σ by the commitment sequence must be acyclic.

The causal ordering referenced in condition (C2) is not assumed as a primitive background structure. Instead, it is induced by the ordering of commitment events themselves. Each commitment introduces a partial ordering relation on the committed record set Σ corresponding to the irreversible sequence in which records are formed. The acyclicity requirement therefore ensures that the admissible commitment sequence defines a consistent causal partial order on Σ rather than presupposing one.

- **(C3) BCB compatibility:** The resulting committed state satisfies $N(\Sigma') \le N\_BCB$.
- **(C4) TPB compatibility:** The transition rate satisfies $\mathcal{R} \le \mathcal{R}\_TPB^{max} \cdot N\_BCB$.

These conditions represent the minimal constraint set required for commitment consistency within the architectural framework presented here; a full algebraic characterization of the admissibility operator remains an open problem.

Within the VERSF interpretation, the Hamiltonian can be treated as encoding the dynamically permitted transition structure at the quantum level, subject to admissibility constraints. This connection is developed in the Hamiltonian-as-Admissibility-Generator companion paper.

At the macroscopic level, a fifth condition connects admissibility to the law-closure programme: admissible variables must be representable on the stable committed algebra and remain invariant under admissible record exchange. This condition — that the committed record structure must

close under the operations it generates — is what makes physical law stable rather than merely local, and is developed in the law-closure companion papers.

Conditions (C3) and (C4) make explicit that Admissibility is not independent of BCB and TPB — it incorporates their constraints as necessary conditions. Physical law, on this view, *is* the admissibility structure: the minimal set of conditions any commitment must satisfy to become a stable physical fact. The full operator-algebraic formalization of $\mathcal{A}$ as a closed operator on the space of measurable maps $\mathcal{T}$, using von Neumann algebra techniques, is identified as a priority for future work.
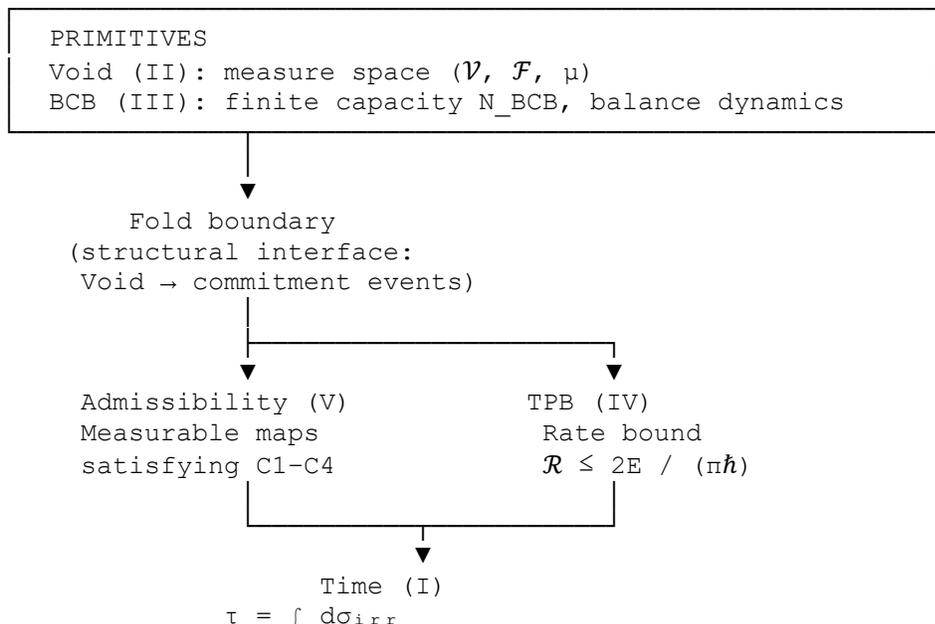
7.3 Distinction from Constructor Theory

Admissibility in VERSF is structurally analogous to constructor theory's notion of possible and impossible tasks (Deutsch & Marletto 2015), but differs in two important respects. First, constructor theory is agnostic about the substrate in which possibilities are defined; VERSF grounds admissibility in the Void measure space. Second, constructor theory does not provide a rate structure; VERSF's admissibility conditions incorporate TPB as a hard bound, yielding quantitative constraints absent from the constructor-theoretic framework.

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8. Integrated Architecture and Logical Dependencies

8.1 Pillar Interactions

The five pillars form an interlocking architecture. Their logical dependencies, tracing from the two primitives to all derived structure, are:

```
  PRIMITIVES
  Void (II): measure space (𝒱, ℱ, μ)
  BCB (III): finite capacity N_BCB, balance dynamics



          ▼
     Fold boundary
  (structural interface:
   Void → commitment events)


          ▼                        ▼
  Admissibility (V)          TPB (IV)
  Measurable maps             Rate bound
  satisfying C1–C4            ℛ ≤ 2E / (πℏ)



                ▼
           Time (I)
        τ = ∫ dσ_irr
```

24

```
      (accumulated commitments
       passing admissibility filter
       within BCB and TPB bounds)
```

Without the Void there is no distinction between reversible and committed, and neither BCB nor Admissibility has a domain of operation. The fold boundary is the structural interface that generates commitment events from Void activity; its detailed treatment is in the fold papers, and its existence is taken as given at the architectural level here. Without BCB there is no finite capacity to bound, and TPB has no denominator. Admissibility and TPB are derived by applying the Void measure space structure and BCB capacity to the question of *which* transitions occur *how fast*. Time is entirely emergent: it is the accumulation of commitments that have passed through the Admissibility filter, within BCB bounds, at rates permitted by TPB.

8.2 Emergence of Physical Reality

Within this structure, physical reality arises from the dynamic interplay between reversible Void potential and irreversible commitment:

1. The Void substrate ($\mathcal{V}$, $\mathscr{F}$, μ) sustains reversible activity with zero committed entropy
2. Admissibility conditions determine which activities are eligible for commitment
3. BCB bounds the total committed content; when saturation is approached, new commitments require dispersal of existing records
4. TPB constrains the maximum rate at which distinguishable commitments can be formed per available capacity
5. Time emerges as the accumulated record of all completed commitments that have passed the admissibility filter

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9. Framework Predictions and Comparison with Competing Frameworks

9.1 Framework-Motivated Scaling Conjectures

All three items below carry the same status: **framework-motivated scaling conjectures**. They are consequences of the commitment-rate architecture that differ from standard predictions and are in principle distinguishable by experiment, but none yet constitutes a completed quantitative derivation. A full master-equation derivation for Conjecture 1 and a quantitative cosmological model for Conjecture 2 are identified as priorities for companion work.

Framework-Motivated Scaling Conjecture 1: Decoherence rate scaling with entropy density.

The following is a framework-motivated scaling conjecture extracted from the commitment-rate architecture; it is not a completed derivation and should not be read as one.

Derivation within the commitment-rate model: In VERSF, quantum decoherence corresponds to the commitment of a system-environment distinction — the irreversible recording of which-path or which-state information by the environment. The rate of such commitment events is constrained by TPB: $\mathscr{R} \leq 2E\_avail / (\pi\hbar)$. In a thermal environment at temperature T, the available free energy scales as $E\_avail \sim k\_B T \cdot N\_modes$. The BCB capacity in the decoherence context is the number of distinguishable environmental degrees of freedom available to record the system state: $N\_BCB,env \sim S\_local / k\_B$. Here S_local/k_B is used as an operational proxy for the number of distinguishable environmental recording channels; it is a reasonable heuristic identification but not a derived equality. The identification $N\_BCB,env \sim S\_local / k\_B$ should be understood as a heuristic mapping between environmental entropy and the number of distinguishable environmental recording channels available to store system information. A full derivation of this relation from BCB capacity dynamics remains an open problem and is left to future work. The scaling relation therefore represents a framework-motivated conjecture rather than a completed prediction. The per-channel decoherence rate (normalized by the number of environmental channels) is:

$\gamma\_dec \sim (2k\_B T / \pi\hbar) \cdot (N\_modes / (S\_local / k\_B))$

At fixed system-environment coupling strength λ and fixed temperature, this yields the scaling conjecture:

$\gamma\_dec \propto E\_avail / (S\_local \cdot \hbar)$ (up to coupling-dependent proportionality factors, under fixed system–environment coupling)

This differs from standard Caldeira–Leggett environmental decoherence, which gives $\gamma\_dec \propto \lambda^2 T$ with no direct dependence on S_local at fixed coupling. The VERSF proposal — that increasing local entropy *suppresses* per-channel decoherence rate at fixed coupling and temperature — is in principle testable in quantum isolation experiments comparing decoherence timescales in systems embedded in thermal environments of varying entropy density (e.g., photonic baths vs. phononic baths at equal temperature but different mode densities).

Framework-Motivated Scaling Conjecture 2: Possible enhancement of early structure formation.

In the early universe ($z \gtrsim 10$), BCB capacity was far from saturation at cosmological scales while TPB limits were near-saturated by the high energy density of the early hot plasma. The combination of low $N(\tau)/N\_BCB$ and high E_avail suggests a possible enhancement of early structure formation under the commitment-rate model — anomalously high rates of gravitational record-formation relative to standard ΛCDM predictions from gravitational instability alone.

This is at least qualitatively compatible with recent observations of unexpectedly massive early galaxies at $z \sim 10$–12 (Labbé et al. 2023; Naidu et al. 2022), though the mechanism is not yet worked out quantitatively. A quantitative cosmological model using TPB-derived commitment rate equations calibrated against JWST galaxy mass functions is identified as a priority for future work.

Framework-Motivated Scaling Conjecture 3: Possible discrete propagation signatures.

The step-valued nature of VERSF time in discrete commitment regimes implies minimum temporal intervals. Since the maximum energy available per commitment is E_avail, the minimum time per commitment is:

$$\Delta t\_min \sim \pi\hbar / (2E\_avail)$$

which recovers Planck-scale discreteness ($\Delta t\_min \sim t\_P$) when E_avail $\sim$ E_P. At intermediate energies, this is a possible phenomenological consequence — contingent on the additional assumption that TPB-limited commitment discreteness couples to effective field propagation — potentially manifesting as an energy-dependent propagation correction of the form:

$$\delta v/c \sim E\_\gamma / E\_P$$

testable through high-energy cosmic ray and gamma-ray burst timing observations (e.g., with Fermi-LAT). This coupling assumption is not derivable from the five-pillar architecture alone and requires separate development.

9.2 Comparison with Competing Frameworks

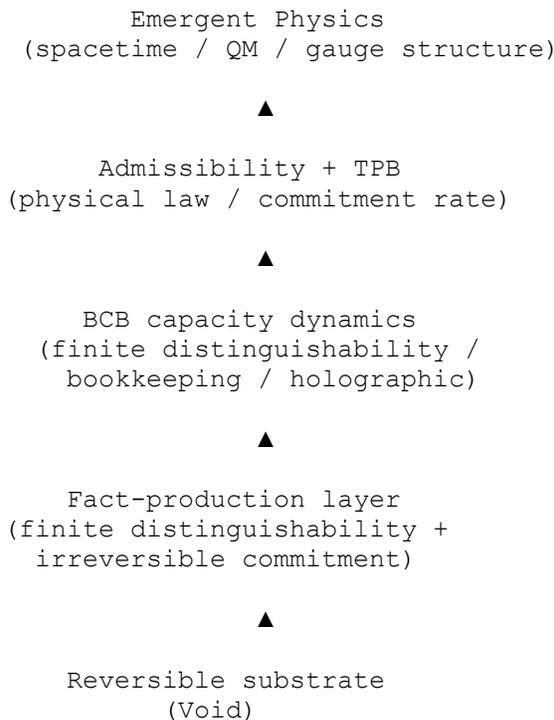| Feature	VERSF	Causal Set Theory	Loop Quantum Gravity	Constructor Theory	Penrose CCC
Substrate	Void (measure space)	None explicit	Spin network	None explicit	Conformal geometry
Time	Emergent (commitments)	Emergent (causal order)	Emergent (Hamiltonian)	Not addressed	Cyclic conformal
Rate constraint	TPB (explicit, derived)	None	None	None	None
Admissibility	Explicit (C1–C4)	Causal order	Diffeomorphism inv.	Possible/impossible tasks	Conformal symmetry
Entropy dynamics	Central (BCB)	Not addressed	Semi-classical	Not addressed	Entropy reset at aeon boundary
Holographic scaling	Targeted / interpreted via BCB	Not addressed	Semi-classical limit	Not addressed	Assumed
Framework proposals	Yes (3 above)	Limited	Limited	Limited	Limited
Lorentz invariance	Targeted / emergent at	Exact at large scales	Exact by construction	N/A	Exact

Feature	VERSF	Causal Set Theory	Loop Quantum Gravity	Constructor Theory	Penrose CCC
	coarse-grained level				

VERSF's primary advantages are the inclusion of rate dynamics (TPB), explicit distinguishability accounting (BCB), and an operationally grounded substrate (Void). Unlike Penrose's CCC, which retains continuous geometry and imposes entropy boundary conditions by hand at aeon boundaries, VERSF interprets entropic behavior as emerging from BCB capacity dynamics throughout cosmic history. CCC's conformal rescaling at aeon transitions has no analog in VERSF, which predicts monotonically increasing τ with no cyclic reset.

9.5 The VERSF Architectural Stack *(operational layering used in this paper)*

The diagram in Section 2.0 illustrates the development order of papers within the VERSF research programme. The architectural stack presented here instead shows the ontological layering of the framework itself, independent of publication order.

The full layered structure of the programme, from deepest substrate to observable physics, is:

```
        Emergent Physics
  (spacetime / QM / gauge structure)


                ▲

      Admissibility + TPB
  (physical law / commitment rate)

                ▲

    BCB capacity dynamics
  (finite distinguishability /
    bookkeeping / holographic)

                ▲

    Fact-production layer
 (finite distinguishability +
   irreversible commitment)

                ▲

    Reversible substrate
          (Void)
```

Each level depends on the one below it; no level can be derived while skipping an intermediate layer. The present paper operates primarily at the BCB/TPB and Admissibility levels, taking the substrate and fact-production layers as compressed architectural primitives and leaving the emergent physics as downstream consequences developed in companion papers.

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10. Conclusion

The Void Energy–Regulated Space Framework proposes that fundamental physical phenomena are better understood by examining the constraints governing distinguishability, finite capacity, and irreversible commitment within a reversible substrate.

This paper has formalized five foundational pillars — Time as Change, the Void Substrate, Bit Conservation and Balance, Ticks Per Bit, and Admissibility — and demonstrated their logical interdependencies. Two pillars, the Void and BCB, are taken as primitives; all remaining structure is derived. The Void is given a precise mathematical characterization as a measure space with the explicit justification that this is the minimal structure sufficient to quantify reversible potential without presupposing geometry or causal order. The TPB rate equations are dimensionally consistent throughout, with notation standardized to distinguish total commitment rate, per-bit rate, and emergent time accumulation rate. The decoherence scaling conjecture follows as a framework-motivated consequence of the commitment-rate structure within the framework.

Taken together, these pillars constitute an operational architecture for the emergence of physical reality: the Void provides the substrate; BCB governs finite distinguishability capacity and its balance; Admissibility filters which processes may commit; TPB constrains commitment throughput; and Time emerges as the accumulated measure of all completed admissible commitments.

The VERSF framework does not claim to be complete. The main contribution of this paper is to identify the minimal structural architecture that links the earlier VERSF strands — BCB, TPB, the fold and Void papers, and the law-closure programme — into one explicit dependency map, and to demonstrate that two framework primitives (the Void and BCB), together with standard thermodynamic and quantum-information constraints, are sufficient to ground the remaining structure developed here. The specific formalizations introduced here — the measure-space Void, the TPB rate notation, the admissibility conditions — are working representations rather than finished foundations; the companion papers remain authoritative on their respective topics.

This paper is intended to serve as the entry point to the architectural layer of the VERSF programme. The deeper distinguishability dynamics developed in the DDF and canon papers represent a more primitive ontological layer beneath the architectural framework presented here. The present work therefore provides the first integrated map of how the physical constraint structure — Void, BCB, TPB, admissibility, and temporal accumulation — organizes the emergent physics derived throughout the broader paper set. Three structural aids are provided for orientation: the programme diagram (Section 2.0) is a paper-to-paper dependency map showing

how companion papers relate; the ontological stack (Section 2.1) is the deepest conceptual ordering of the framework from distinguishability through to emergent physics; and the architectural stack (Section 9.5) is the operational layering used in this paper, from substrate through to observable consequences. The five core invariants in Section 2.2, the notation glossary in Section 2.3, and the three-layer separation in Section 2.4 together constitute the stable reference frame against which all other papers in the set should be read. BCB, TPB, fold geometry, admissibility, and emergent physics papers each develop one strand of this map in detail; the present paper shows how those strands connect. What the framework offers is the clearest current account of how those treatments logically relate: the nature of time, the origin of entropy, and the structure of physical law are not assumed but located as consequences of a finite, reversible substrate and the capacity-balance principle that governs it.

References

Barbour, J. (1999). *The End of Time*. Oxford University Press.

Bekenstein, J. D. (1973). Black holes and entropy. *Physical Review D*, 7(8), 2333.

Bekenstein, J. D. (1981). Universal upper bound on the entropy-to-energy ratio for bounded systems. *Physical Review D*, 23(2), 287.

Bombelli, L., Lee, J., Meyer, D., & Sorkin, R. D. (1987). Space-time as a causal set. *Physical Review Letters*, 59(5), 521.

Bousso, R. (2002). The holographic principle. *Reviews of Modern Physics*, 74(3), 825.

Caldeira, A. O., & Leggett, A. J. (1983). Path integral approach to quantum Brownian motion. *Physica A*, 121(3), 587–616.

Deutsch, D., & Marletto, C. (2015). Constructor theory of information. *Proceedings of the Royal Society A*, 471(2174).

Hawking, S. W. (1974). Black hole explosions? *Nature*, 248, 30–31.

Labbé, I., et al. (2023). A population of red candidate massive galaxies ~600 Myr after the Big Bang. *Nature*, 616, 266–269.

Landauer, R. (1961). Irreversibility and heat generation in the computing process. *IBM Journal of Research and Development*, 5(3), 183–191.

Lloyd, S. (2006). *Programming the Universe*. Knopf.

Margolus, N., & Levitin, L. B. (1998). The maximum speed of dynamical evolution. *Physica D*, 120(1–2), 188–195.

Naidu, R. P., et al. (2022). Two remarkably luminous galaxy candidates at z ≈ 10–12 revealed by JWST. *The Astrophysical Journal Letters*, 940(1), L14.

Penrose, R. (2010). *Cycles of Time: An Extraordinary New View of the Universe*. Bodley Head.

Rovelli, C. (2004). *Quantum Gravity*. Cambridge University Press.

Rovelli, C. (2018). *The Order of Time*. Riverhead Books.

Susskind, L. (1995). The world as a hologram. *Journal of Mathematical Physics*, 36(11), 6377.

't Hooft, G. (1993). Dimensional reduction in quantum gravity. arXiv:gr-qc/9310026.

Appendix A. Mathematical Framing of Distinguishability, Commitment, and Capacity

This appendix provides a compact mathematical framing of the VERSF ontology using structures already familiar from information theory, quantum theory, and operator methods. Its purpose is not to replace the native VERSF development, but to show that the framework can be expressed in a mathematically recognizable language. In particular, it clarifies how the deepest primitive of the programme — distinguishability — may be represented as a metric structure on state space; how commitment may be represented as an irreversible projection or record map; how BCB may be understood as a finite resource constraint on committed distinguishability; and how TPB and admissibility fit naturally into a constrained operation framework.

A.1 Distinguishability as the Deepest Primitive

The deepest primitive in the VERSF ontology is not spacetime, matter, or information as such, but distinguishability: the existence of operationally meaningful differences between physical states. Two states are distinguishable if and only if there exists an admissible procedure that separates them with nonzero reliability.

This can be represented abstractly by a state space $\mathcal{S}$ equipped with a distinguishability measure D:

$(\mathcal{S}, D)$.

The functional $D(\rho, \sigma)$ satisfies the minimal requirement that

$D(\rho, \sigma) = 0 \iff \rho$ and σ are operationally equivalent,

and $D(\rho, \sigma) > 0$ when the two states are physically distinguishable. In quantum settings, a natural choice is the quantum relative entropy,

$$D(\rho \parallel \sigma) = \text{Tr}(\rho \log \rho - \rho \log \sigma),$$

or other distinguishability measures such as trace distance or fidelity-derived metrics. The precise choice is secondary at the architectural level; what matters is that physical state space carries a nontrivial distinguishability structure.

In quantum information theory, distinguishability measures such as relative entropy satisfy the data-processing inequality: distinguishability cannot increase under irreversible operations. Formally, for any completely positive trace-preserving (CPTP) map $\mathcal{E}$, $D(\mathcal{E}(\rho) \parallel \mathcal{E}(\sigma)) \leq D(\rho \parallel \sigma)$. This property aligns naturally with the VERSF commitment framework, where irreversible record formation converts reversible distinguishability into committed distinguishability subject to capacity and thermodynamic cost. In this sense the Distinguishability Cost Principle can be viewed as the physical manifestation of distinguishability monotonicity under irreversible processes — grounding an architectural claim of the programme in a well-established result of quantum information theory.

In this language, the VERSF claim that distinguishability is ontologically primary means that physical reality begins not with pre-given objects, but with a relational structure of separable states.

A.2 Commitment as Irreversible Record Formation

A commitment event occurs when a previously reversible distinction becomes stably recorded. In the VERSF vocabulary, this is the moment at which distinguishability becomes a physical fact — the point at which a bit is formed: a committed distinguishability event.

At an abstract level, this can be modeled as a map

$T: \mathcal{S}\_\text{rev} \rightarrow \Sigma,$

from reversible state space to a committed-record space Σ. In quantum language, the simplest representation is an irreversible projection onto a stable record subspace:

$\rho \mapsto \sum_i \Pi_i \rho \Pi_i,$

where the Π_i are record projectors. This is not asserted as the complete VERSF ontology of commitment, but as a familiar mathematical analogue: commitment corresponds to the loss of reversible superposed distinguishability in favor of stable recorded distinguishability.

The key physical content is that commitment is not mere evolution. It is a transition from reversible distinguishability to irreversible record. That is why commitment, rather than unitary evolution alone, serves as the foundation of time and entropy within the framework.

A.3 BCB as a Finite Resource Constraint

Once commitment is understood as stable recorded distinguishability, the BCB principle can be stated as a finite resource law: any bounded system or causal region can sustain only a finite quantity of committed distinguishability.

Let $N(\tau)$ denote the number of committed distinguishability records at VERSF time τ. Then BCB asserts that

$$N(\tau) \leq N\_BCB,$$

where N_BCB is the effective distinguishability capacity of the system or region.

This allows BCB to be read as a resource theory of committed distinguishability. The resource is not generic information in the abstract, but physically sustainable irreversible distinction. This is the reason entropy, capacity, and distinguishability become tightly linked in the VERSF programme.

The dynamical balance law is

$$(dN(\tau)) / (d\tau) = \Gamma\_form - \Gamma\_disperse,$$

where Γ_form is the record formation rate and $\Gamma\_disperse$ is the rate at which maintained records become thermodynamically unresolved and release capacity back into the reversible substrate.

This framing makes clear that what BCB conserves is not particular records, but the total bookkeeping budget for distinguishable committed structure.

A.4 TPB as the Rate of Resource Conversion

If BCB supplies the finite capacity for committed distinguishability, TPB supplies the rate at which reversible potential is converted into committed record.

Let $\mathscr{R}(t)$ denote the total commitment rate in coordinate time. Then

$$(d\tau) / (dt) = \mathscr{R}(t).$$

Normalizing by available distinguishability capacity gives the TPB rate,

$$\mathscr{R}\_TPB = (\mathscr{R}) / (N\_BCB).$$

At the physical level, this rate is bounded by standard quantum speed limits, giving

$$\mathscr{R}(t) \leq (2\ E\_avail) / (\pi\ \hbar),$$

and therefore

$$\mathscr{R}\_TPB \leq (2\ E\_avail) / (\pi\ \hbar\ N\_BCB).$$

This identifies TPB as a commitment throughput law: a bound on how rapidly distinguishability can become irreversibly recorded relative to the available capacity for doing so. In this sense TPB is naturally read as a rate-of-conversion law in a resource theory of distinguishability commitment.

A.5 Admissibility as the Algebra of Allowed Commitment Operations

Not every reversible transformation may become a committed physical fact. The framework therefore introduces admissibility as the constraint structure on commitment.

If T denotes a candidate commitment map, admissibility is represented by a predicate

$\mathcal{A}(T)$ in $\{0, 1\}$,

with $\mathcal{A}(T) = 1$ if and only if the candidate operation satisfies the required consistency conditions. At minimum these include conservation, causal consistency, BCB compatibility, and TPB compatibility.

Thus admissibility defines the set of physically permitted commitment operations:

$\mathcal{A}\_adm = \{ T \mid \mathcal{A}(T) = 1 \}$.

This set plays a role analogous to the allowed-operation sets in other physical resource theories. In the VERSF setting, however, the resource being governed is committed distinguishability. Physical law is therefore interpreted as the structure of allowed commitment operations on the reversible substrate.

At a more developed level this suggests an operator-algebraic completion in which the stable committed-record algebra closes under admissible operations. That fuller treatment is deferred to companion work.

A.6 Time as Ordered Accumulation of Commitment

With the above structures in place, VERSF time takes its simplest form. Time is not a background parameter but the ordered accumulation of admissible commitment events:

$\tau = \int d\sigma\_irr$.

Equivalently, τ is the count of committed distinguishability events — the ordering variable of irreversible record formation.

This account is compatible with coarse-grained thermodynamic time because irreversible commitment is associated with entropy production:

$d\tau \propto dS\_irr \geq 0$.

The asymmetry of time is therefore not imposed externally. It follows from the asymmetry of commitment itself: once a distinction is irreversibly recorded, the state of the world is no longer operationally equivalent to the state before the record existed.

A.7 Summary of the Mathematical Correspondence

The VERSF ontology can be summarized in the following mathematical correspondence:

VERSF Concept	Mathematical Object
Distinguishability	$(\mathcal{S}, D)$
Commitment	$T: \mathcal{S}\_\text{rev} \to \Sigma$
BCB	$N(\tau) \le N\_\text{BCB}$
TPB	$\mathcal{R}\_\text{TPB} = \mathcal{R} / N\_\text{BCB}$
Admissibility	$\mathcal{A}\_\text{adm}$
Time	$\tau = \int d\sigma\_\text{irr}$

This appendix demonstrates that the VERSF primitives admit a natural mathematical representation using structures already familiar in modern theoretical physics. A full mathematical development remains an open programme, but the correspondence presented here shows that the framework can be embedded within established theoretical language — and that its core claims, including the monotonicity of distinguishability under irreversible operations, connect directly to known results in quantum information theory.

Appendix B. Record Formation, Irreversibility, and the Thermodynamic Origin of Temporal Ordering

This appendix clarifies the thermodynamic interpretation of commitment events within the VERSF framework and shows how the accumulation of such events naturally generates temporal ordering. The purpose is not to introduce new postulates, but to demonstrate that the commitment architecture described in the main text is closely aligned with established principles of statistical mechanics, information thermodynamics, and quantum measurement theory.

B.1 Record Formation as Physical Stabilization

A central concept of the VERSF framework is the commitment event: the transition by which a previously reversible distinction becomes stably represented in the committed layer. A commitment is therefore not merely a mathematical update of a state description — it corresponds to the physical stabilization of a distinguishability relation.

Operationally, a physical record must satisfy three properties:

- **Separability** — distinct outcomes correspond to distinguishable physical states.
- **Amplification** — the distinction is encoded in macroscopic or otherwise robust degrees of freedom.
- **Persistence** — the record remains accessible and stable over timescales longer than the microscopic dynamics that generated it.

These conditions appear naturally in measurement theory. In quantum experiments, a detector outcome becomes meaningful only once the microscopic interaction has been amplified into a stable macroscopic record correlated with the measured system. Within the VERSF vocabulary, this stabilization process is precisely what is meant by commitment.

B.2 Irreversibility and Entropy Production

The formation of stable records is not thermodynamically neutral. Processes that amplify and stabilize distinctions typically involve dissipation, environmental coupling, or coarse-grained irreversibility. Modern nonequilibrium statistical mechanics describes such processes in terms of entropy production.

If a physical trajectory is compared with its time-reversed counterpart, the difference in forward and reverse probabilities is quantified by irreversible entropy production. Record formation increases this asymmetry because the resulting state contains information that cannot be reversibly erased without additional physical work.

This observation motivates the following principle.

Record–Irreversibility Principle: Any physical process that creates a stable, operationally accessible record of a previously reversible distinction involves positive irreversible entropy production in the enlarged physical system.

This principle provides a natural thermodynamic interpretation of commitment. A commitment event corresponds to the creation of a physically stabilized distinction, and such stabilization generically requires dissipation or entropy generation somewhere in the surrounding degrees of freedom.

B.3 Commitment and the Arrow of Time

Because commitment events involve irreversible entropy production, they introduce a fundamental asymmetry between past and future. Once a record has formed, the state of the system is no longer operationally equivalent to the state that preceded the record.

In VERSF, the arrow of time is therefore not introduced as a primitive feature of spacetime. Instead, temporal asymmetry emerges from the physical asymmetry of commitment events. The accumulation of such events defines the VERSF time variable:

$\tau = \int d\sigma\_irr$

where dσ_irr denotes the differential count measure of irreversible commitment events.

Since commitment events are associated with entropy production, one may write schematically:

dτ ∝ dS_irr ≥ 0.

This relation should not be interpreted as identifying time with entropy itself. Rather, entropy measures the thermodynamic cost and dispersal structure of commitment, while time measures the ordered accumulation of commitment events.

B.4 Distinction from "Time Equals Entropy"

It is sometimes suggested in thermodynamic interpretations of physics that time is simply another name for entropy increase. VERSF adopts a more precise formulation.

Entropy is a state function describing the statistical structure of a system's degrees of freedom. Time in the VERSF sense is instead an ordering variable defined by the sequence of irreversible record-forming events. Thus the framework distinguishes clearly between:

- **Entropy** — the thermodynamic cost structure associated with maintaining distinguishable records.
- **Commitment** — the physical event by which a distinction becomes stably recorded.
- **Time** — the ordered accumulation of such commitment events.

This distinction allows the framework to retain the deep link between thermodynamic irreversibility and temporal direction while avoiding the conceptual difficulties of identifying time directly with entropy.

B.5 Summary

The VERSF commitment architecture is consistent with a broad thermodynamic insight: stable physical records require irreversible processes. Within this interpretation:

- **Distinguishability** represents reversible separability of states.
- **Commitment** represents the irreversible stabilization of those distinctions.
- **Entropy** measures the thermodynamic cost of stabilization.
- **Time** measures the ordered accumulation of stabilized distinctions.

Temporal ordering is thus understood as the historical record of irreversible distinguishability commitments occurring within a finite-capacity physical substrate.