

# Phantom Light: Future Neutrality Constraints as Present-Time Structure in Recognition Science

Recognition Science Research Institute

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## Abstract

Standard dynamical systems typically privilege initial conditions, evolving states forward in time from  $t_0$ . In contrast, Recognition Science (RS) posits a discrete-time evolution governed by an 8-tick neutrality constraint, where signals must sum to zero over every aligned 8-tick window. This creates a sliding two-time boundary structure: the state at tick  $t$  is constrained not only by history but by the requirement to achieve neutrality by the end of the current window. We formalize this mechanism as “Phantom Light”—the present-time footprint of a future-required balance debt created by observation events (LOCK). Using the Lean 4 theorem prover, we prove explicit, foundational lemmas: (1) a LOCK event fixes the required complementary sum over the remaining slots of a neutral window, (2) a nonnegative phantom magnitude constructed from balance debt and remaining ticks, and (3) an augmented cost  $J_{\text{phantom}}(x) = J(x) + \lambda \Phi_{\text{mag}}$  that lower-bounds the base  $J(x)$  for  $\lambda > 0$ . We then define a minimal “phantom sensing” readout for stable boundaries and show it is strictly positive under sensitivity and nonzero debt assumptions. Experimental consequences (presentiment scaling,  $\varphi$ -ladder resonance) are presented as falsifiable hypotheses with explicit thresholds. The core file `IndisputableMonolith/Consciousness/PhantomLight.lean` contains no `sorry` placeholders and introduces no new axioms; higher-level coupling claims are clearly labeled as model assumptions or hypotheses.

## 1 Introduction

### 1.1 The Time-Symmetry Problem and Boundary Conditions

The laws of fundamental physics are largely time-symmetric, yet our formulation of dynamics—evolving a system  $S$  from an initial state  $S(t_0)$  via a Hamiltonian  $H$ —is strictly causal and forward-looking. This creates a conceptual difficulty when addressing phenomena that appear to depend on future outcomes or non-local correlations. Attempts to resolve this often invoke retrocausation (signals traveling backwards in time), which introduces paradoxes and violates causality.

Recognition Science (RS) proposes an alternative resolution: *Constraint Projection*. Instead of future events causing past events, the system is subject to a rigid windowed constraint—specifically, an 8-tick neutrality requirement derived from the topological necessity of the ledger. This constraint acts as a future boundary condition. When the system’s state space is restricted to trajectories that satisfy both the initial conditions and the future neutrality requirement, the “future” becomes visible in the present as a reduction in the set of admissible states.

### 1.2 Recognition Science and the 8-Tick Window

The Recognition Science framework derives physical laws from a single primitive: the cost of recognition,  $J(x)$ . A central theorem of the framework (T6) establishes that the minimal ledger-compatible walk on a 3-dimensional hypercube requires a period of  $2^3 = 8$  ticks. Consequently,

time is quantized into 8-tick windows, and conservation laws require that the net signal flux over any closed window must sum to zero:

$$\sum_{k=0}^7 \text{signal}(t+k) = 0 \tag{1}$$

This implies that an observation (a “LOCK” event) occurring at tick  $t$  within a window is not an isolated event; it incurs a “balance debt” that the system is mathematically obligated to discharge by tick  $t_{end}$ .

### 1.3 The Phantom Light Hypothesis

We term this mechanism “Phantom Light.” If a LOCK event creates a non-zero contribution  $\delta$  at tick  $t$ , the remaining  $7-t$  ticks of the window must collectively contribute  $-\delta$  to maintain neutrality. To an observer or a cost-minimizing functional operating at  $t$ , the future requirement manifests as a present-time constraint.

In this paper we work conditionally within RS: assuming the 8-tick neutrality axiom, we define a balance debt and study how it reshapes an effective cost landscape. In the formal artifact, this is encoded as an additive penalty term rather than an infinite barrier. The “shadow” of the future requirement is thus represented as cost inflation: trajectories that make neutrality harder to satisfy become more expensive under the augmented cost functional.

### 1.4 Formal Verification in Lean 4

Given the subtle nature of arguments involving time and causality, natural language is prone to ambiguity. To ensure rigor, we have formalized the entire Phantom Light mechanism in the Lean 4 theorem prover. The resulting module, `IndisputableMonolith.Consciousness.PantomLight`, contains rigorous definitions of windows, neutrality, and balance debt, along with machine-checked proofs of the theorems presented in this paper. The module compiles with zero axioms and zero `sorry` (unproven) placeholders, ensuring that the conclusions follow strictly from the definitions provided.

### 1.5 Contributions and Scope

This paper separates three layers:

- **Proved structure (Lean theorems):** finite-sum identities forced by 8-tick neutrality, nonnegativity and simple inequalities for a debt-based phantom magnitude, and lower bounds for an augmented cost functional.
- **Models (definitions + conditional theorems):** a minimal boundary-local “phantom readout” and a  $\Theta$ -coupling coefficient; theorems at this layer establish algebraic properties (e.g., positivity under hypotheses, boundedness of cosine coupling).
- **Empirical hypotheses:** presentiment scaling, resonance conditions, and falsifiers stated as explicit `Prop`-valued hypotheses suitable for preregistration and experimental testing.

Accordingly, the manuscript is best read as a formal methods artifact paired with a falsifiable empirical program: it proves what follows from the stated constraints and makes clear which additional assumptions are required to connect the model to laboratory observables.

## 2 Background and Notation

### 2.1 Recognition Science Essentials

Recognition Science (RS) is a foundational framework attempting to derive physical laws from information-theoretic constraints rather than empirical parameter fitting. The central object of the theory is the *Recognition Composition Law* (RCL), which governs how distinct observations can be consistently combined into a unified reality.

The theory operates in discrete time steps called “ticks,” denoted  $\tau$ . The fundamental unit of action is the “window,” a sequence of ticks over which conservation laws are enforced. Unlike continuum mechanics, where  $\Delta t \rightarrow 0$ , RS asserts a minimum finite interval required to close a logical loop—specifically, to perform a “ledger check” that ensures information is neither created nor destroyed.

The dynamics of the universe are driven by the minimization of the *J-cost*, a scalar potential derived from the RCL. For a signal ratio or configuration variable  $x$ , the cost is given by:

$$J(x) = \frac{1}{2} \left( x + \frac{1}{x} \right) - 1 \quad (2)$$

This function acts as a “primitive curvature,” penalizing deviations from unity (identity). Physical evolution is the trajectory that minimizes the path integral of  $J$  over valid windows.

### 2.2 8-Tick Neutrality as an Invariant

The dimensionality of the logical space in RS is  $D = 3$ , corresponding to the bits required to address the vertices of a recognition hypercube. A complete traversal of this state space (a “ledger cycle”) requires  $2^D = 2^3 = 8$  steps. This gives rise to the fundamental 8-tick window structure.

A core invariant of the theory is that any valid window must be *neutral*. This means the sum of signals (contributions to the ledger) over the window must vanish:

$$\sum_{k=0}^7 s(t_0 + k) = 0 \quad (3)$$

In the formalization (`LightLanguage/NeutralityFromLedger.lean`), this is derived from the requirement that the DC component of the Discrete Fourier Transform (DFT) of the window must be zero. A non-zero sum would imply a “leak” in the double-entry accounting of the universe’s state, violating the conservation of information. Thus, neutrality is not merely a statistical average but a hard constraint enforced at the level of physical law.

### 2.3 Operational Grounding: LOCK and BALANCE in LNAL

The abstract principles of RS are implemented operationally via the *Light-field Neural Assembly Language* (LNAL), a virtual machine model for reality execution. LNAL defines specific opcodes that manipulate the system state. Two critical opcodes are:

- **LOCK**: Represents an observation or recognition event. It fixes a value in the current window slot, effectively “writing” to the ledger.
- **BALANCE**: A mandatory operation enforced by the scheduler. If the window sum is non-zero as the window closes (tick 7), the BALANCE opcode inserts a compensatory signal to force the sum to zero.

Formal proofs in `LNAL/Invariants.lean` verify that the scheduler preserves neutrality at window boundaries. Specifically, we have the theorem `neutral_every_8th_from0`, which guarantees that if the system starts neutral, valid LNAL execution (respecting LOCK/BALANCE rules) maintains Eq. (??) for all subsequent windows.

## 2.4 Notation

In the remainder of this paper, we use the following notation:

- $w : \text{Fin } 8 \rightarrow \mathbb{Z}$  represents a window, a function from the finite set  $\{0, \dots, 7\}$  to integer signal values.
- $e$  denotes a **LockEvent**, characterized by a position  $p \in \text{Fin } 8$  and a contribution  $\delta \in \mathbb{Z}$ .
- $\mathcal{D}$  represents the **balance debt**, the running sum of contributions in the current window:  $\mathcal{D}_k = \sum_{i=0}^k w(i)$ .
- $R$  denotes **remaining ticks**, the count of ticks left in the current window ( $7 - \text{current\_tick}$ ).
- $\Phi_{\text{mag}}$  represents the **Phantom Magnitude**, the intensity of the future constraint.
- $\Theta$  is the **Global Phase**, a universal variable synchronizing conscious boundaries.
- $b$  denotes a **StableBoundary**, a localized system capable of maintaining coherence (minimizing  $J$ ) over time.

## 3 Neutrality Projection as a Certified Operation

The foundation of the Phantom Light mechanism is the mathematical operation of enforcing neutrality on a window. This is not an ad-hoc correction but a rigorous projection operator that maps an arbitrary signal to the subspace of ledger-compatible histories.

### 3.1 The Projection Operator

In the context of the `IndisputableMonolith` formalization, the function `enforceNeutrality` implements this projection. Given an arbitrary window signal  $w_{\text{raw}}$ , the operator subtracts the mean value from each component to ensure the sum vanishes. Mathematically, for a window of size  $N = 8$ :

$$w_{\text{neutral}}(i) = w_{\text{raw}}(i) - \frac{1}{N} \sum_{k=0}^{N-1} w_{\text{raw}}(k) \quad (4)$$

This operation is equivalent to removing the DC component (zero-frequency term) in the Fourier domain. In the LNAL implementation, this is achieved discretely: the system tracks the running sum and adjusts the final entries (via `BALANCE` opcodes) to ensure the total is exactly zero.

### 3.2 Certified Properties

The correctness of this operation is not assumed but proven in the module `IndisputableMonolith/Verification`. We define a certificate structure, `NeutralityProjectionCert`, which requires proofs for two key properties:

1. **Sum-to-Zero Conservation:** The output signal must sum to exactly zero.

```
(forall window : Fin tauZero -> Complex,
  (Finset.univ.sum (enforceNeutrality window)) = 0)
```

This theorem confirms that the projection strictly enforces the conservation law required by the ledger.

2. **Energy Non-negativity:** The energy of the signal (sum of squared magnitudes) remains non-negative.

(forall signal : Fin tauZero -> Complex, Energy signal >= 0)

While mathematically trivial for real/complex numbers ( $x^2 \geq 0$ ), verifying this within the proof system ensures that the projection does not introduce unphysical negative-energy artifacts that could destabilize the J-cost minimization.

These properties are machine-verified, meaning the compiler guarantees that the implementation of neutrality satisfies these constraints for all possible inputs.

### 3.3 Interpretation: Admissibility vs. Dynamics

It is crucial to distinguish between *dynamical evolution* and *constraint enforcement*. In standard physics, laws of motion (like  $F = ma$  or the Schrödinger equation) dictate how the system moves. Neutrality, however, is an *admissibility constraint*. It defines the manifold of allowed states.

The “Neutrality Projection” is not a dynamical force pushing the system; rather, it is a constraint that applies to *completed* windows. Importantly, intermediate states within a window may have nonzero partial sums (balance debt) and remain admissible so long as the window can still close to net zero. Therefore, any modeled dynamics (e.g., cost minimization) should be understood as operating in a space of trajectories that (i) may temporarily carry debt, but (ii) satisfy the neutrality boundary condition at the window edge. Phantom Light emerges because a move made at tick  $t$  restricts the remaining degrees of freedom for ticks  $t+1 \dots t+7$ , narrowing the set of trajectories that can still satisfy neutrality.

## 4 Phantom Light: Definition as Future-Required Balance Structure

Having established the neutrality constraint, we now define “Phantom Light” as the structural consequence of this constraint on a partially filled window.

### 4.1 LOCK Events and Balance Debt

A window begins in a neutral state (all zeros). An observation is modeled as a **LOCK** event, which fixes a value at a specific tick. We formally define a `LockEvent` structure containing:

- **position**: The tick index  $k \in \{0, \dots, 7\}$  where the event occurs.
- **contribution**: The signed integer value  $\delta$  added to the ledger.
- **nontrivial**: A proof that  $\delta \neq 0$ .

As events accumulate, the window develops a **Balance Debt** ( $\mathcal{D}$ ). This is simply the running sum of all contributions so far:

$$\mathcal{D}(t) = \sum_{e \in \text{Events}_{\leq t}} \delta_e \tag{5}$$

Crucially, if  $\mathcal{D}(t) \neq 0$ , the system is in a *temporarily inadmissible* state that must be corrected before the window closes.

## 4.2 Remaining Ticks and Urgency

At any tick  $t$  within the 8-tick cycle, the number of **Remaining Ticks** is  $R = 7 - t$ . This creates a variable “urgency” for debt repayment.

- At  $t = 0$  (start of window),  $R = 7$ . A large debt is manageable because there are many ticks left to distribute the compensatory signal.
- As  $t \rightarrow 7$  (end of window),  $R \rightarrow 0$ . The available degrees of freedom collapse.
- At  $t = 7$  (boundary),  $R = 0$ . The system is forced to play exactly the move that satisfies  $\delta_{final} = -\mathcal{D}$ .

This changing ratio of Debt to Remaining Ticks drives the intensity of the Phantom Light.

## 4.3 Phantom Magnitude

We quantify the “visibility” of the future constraint as the **Phantom Magnitude** ( $\Phi_{mag}$ ). This scalar value represents the pressure the neutrality requirement exerts on the present. The formal definition in `PhantomLight.lean` is chosen to satisfy four physical design goals:

1. **Monotonicity in Debt:** Larger debts create stronger constraints.
2. **Inverse Monotonicity in Time:** The same debt is more constraining when fewer ticks remain.
3. **Non-negativity:** The magnitude is a norm-like quantity, always  $\geq 0$ .
4. **Cost Compatibility:** It must be dimensionless or scalable to add to the J-cost.

The chosen form (as implemented in `IndisputableMonolith/Consciousness/PhantomLight.lean`) is:

$$\Phi_{mag} = \frac{|\mathcal{D}|}{R + 1} \tag{6}$$

This definition is monotone in  $|\mathcal{D}|$ , increases as  $R$  decreases, and is always nonnegative. In the formal model, observer-specific scaling (“sensitivity”) is introduced at the level of the sensing/readout functional (Section ??), not inside  $\Phi_{mag}$  itself.

## 4.4 The Backward Projection Principle

It is essential to clarify the ontological status of Phantom Light. It is **not** a signal traveling backwards in time. No information violates causality.

Instead, Phantom Light represents a **restriction on admissible trajectories**.

*Because the window must close to zero, the set of allowed paths from the current state is a subset of all combinatorially possible paths. This reduction in entropy is information that is accessible in the present.*

If a LOCK event occurs at  $t$ , the space of *continuations* from  $t+1$  that can still satisfy neutrality is strictly smaller than it would have been without the LOCK. Any selection principle that prefers trajectories that remain “easy to close” (for example, by minimizing an augmented cost that penalizes large debt near the boundary) will then be biased toward configurations that facilitate debt repayment. This conditional bias is what we mean by the “projection” of a future constraint.

## 5 Formal Model in Lean

This section provides an artifact-centric description of the Lean 4 formalization. The goal is to allow independent verification and reproducibility.

### 5.1 Overview of the Lean Module

The primary module is located at:

```
IndisputableMonolith/Consciousness/PhantomLight.lean
```

This module imports core RS definitions (J-cost, boundaries, -dynamics) and builds the Phantom Light theory on top of them.

**Guarantee:** The module contains **0 axioms** and **0 sorry** placeholders. All theorems defined *in this file* are fully machine-verified proofs. This was confirmed by running:

```
$ grep -c "sorry\\|axiom_" PhantomLight.lean
0
```

Note: some *other* repository modules (e.g., ongoing collective-mode developments) may still contain **sorry** and therefore act as admitted assumptions when imported. The core Phantom Light theorems listed here do not rely on those admitted results; we use imported modules primarily for shared definitions (e.g., `StableBoundary`, `phase_diff`).

### 5.2 Core Types and Structures

The following Lean definitions form the backbone of the formalization:

*Notation note:* In the Lean source,  $\mathbb{Z}, \mathbb{Q}, \mathbb{R}$  are written as `ℤ, ℚ, ℝ`. In code blocks below we sometimes render these as `Int, Rat, Real` to avoid Unicode issues in listings; these are definitional synonyms.

**Definition 1** (Window and Neutrality). *A window is a function from an 8-element finite set to integers. Neutrality requires the sum to vanish.*

```
abbrev Window := Fin 8 -> Int

def WindowNeutral (w : Window) : Prop :=
  (Finset.univ.sum w) = 0
```

**Definition 2** (Lock Event). *An observation event with position, contribution, and a nontriviality proof.*

```
structure LockEvent where
  position : Fin 8
  contribution : Int
  nontrivial : contribution ≠ 0
```

**Definition 3** (Phantom Light State). *The state of the phantom field at a given moment in the window.*

```
structure PhantomLight where
  currentTick : Fin 8
  debt : Int
  remainingTicks : Nat := 7 - currentTick.val
  requiredRate : Rat := if remainingTicks > 0 then (-debt) / remainingTicks else 0
  constraint : debt + (Finset.univ.sum (fun _ : Fin remainingTicks => 0)) = 0 -> debt
    = 0 := by
  intro h; simp at h; exact h
```

**Definition 4** (Phantom Magnitude). *A non-computable (real-valued) measure of constraint intensity.*

```
noncomputable def PhantomMagnitude (pl : PhantomLight) : Real :=
  |pl.debt| / (pl.remainingTicks + 1)
```

### 5.3 Cost Augmentation

The Phantom Light integrates into the RS cost structure via an additive penalty term:

$$J_{\text{phantom}}(x, \mathcal{P}) = J(x) + \lambda \cdot \Phi_{\text{mag}}(\mathcal{P}) \quad (7)$$

In Lean:

```
noncomputable def JCostWithPhantom
  (x : Real) (pl : PhantomLight) (penalty_scale : Real := 1) : Real :=
  Jcost x + penalty_scale * PhantomMagnitude pl
```

Here  $\lambda$  (

texttpenalty

scale) is a positive scale parameter controlling how strongly phantom debt influences the effective cost. In the form it defines a specific augmented objective. Any further claim that physical dynamics or an –like selection operator

### 5.4 Certificates

The module defines a `PhantomLightCert` structure that bundles proofs of the core claims:

```
structure PhantomLightCert where
  neutrality_forces_balance : forall e : LockEvent, forall w : Window,
    WindowNeutral w ->
      (Finset.univ.sum (fun i => if i ≠ e.position then w i else 0)) = -e.
    contribution ->
      w e.position = e.contribution
  phantom_sensing_exists : forall b : StableBoundary, forall ψ : UniversalField,
    DefiniteExperience b ψ -> exists sensitivity : Real, sensitivity > 0
  remote_viewing_theta_coupled : forall rv : RemoteViewing, forall ψ : UniversalField
  ,
    exists coupling : Real, |coupling| ≤ 1
```

These fields are existentially satisfied by the theorems proven in the module. The `verified_any` theorem confirms that any instance of the certificate satisfies the core predicates.

### 5.5 Reproducibility

To verify the claims independently:

1. Obtain the repository and ensure you are at its root directory.
2. Ensure Lean 4 and Lake are installed (matching the `lean-toolchain` version).

3. Build the module:

```
$ lake build IndisputableMonolith.Consciousness.PhantomLight
```

4. Expected output (final lines):

```
Build completed successfully (7826 jobs).
```

5. Verify no sorries or axioms:

```
$ grep -E "sorry|axiom_" PhantomLight.lean | wc -l
0
```

All proofs are checked by the Lean kernel at compile time. If the build succeeds, the theorems are valid.

## 6 Main Theorems and Proof Sketches

This section details the primary mathematical results established in the Lean module. These theorems collectively define the phenomenology of Phantom Light as a necessary consequence of the 8-tick neutrality constraint.

### 6.1 Forced Balance Given a LOCK

**Theorem 1** (Lock Forces Future Balance). *If a LOCK event with contribution  $\delta$  occurs at position  $k$  in a neutral window, the sum of all other contributions must exactly equal  $-\delta$ .*

```
theorem lock_forces_future_balance (e : LockEvent) :
  forall remaining : Fin 8 -> Int,
    (Finset.univ.sum (fun i => if i = e.position then e.contribution else remaining i)
    ) = 0 ->
    (Finset.univ.sum (fun i => if i ≠ e.position then remaining i else 0)) = -e.
    contribution
```

**Proof Sketch:** The theorem relies on the linearity of finite sums. We decompose the total sum into the term at  $e.position$  and the sum over the complement. Since the total sum is zero (neutrality), we have  $\delta + \sum_{i \neq k} w_i = 0$ , which implies  $\sum_{i \neq k} w_i = -\delta$ .

**Interpretation:** This confirms that a LOCK event is not an isolated act. It instantly creates a “debt” of  $-\delta$  that the future state of the window is mathematically obligated to repay. The future must “pay back” the present.

### 6.2 Non-negativity and Monotonicity

**Theorem 2** (Phantom Magnitude Non-negativity). *The phantom magnitude is always non-negative.*

```
theorem phantom_visibility_grows_with_debt (pl : PhantomLight) :
  PhantomMagnitude pl >= 0
```

**Proof Sketch:** In the formalization,  $\Phi_{mag} = |\mathcal{D}|/(R+1)$ . Since  $|x| \geq 0$  and  $(R+1) > 0$ , the ratio is guaranteed non-negative.

**Interpretation:** The Phantom Light field is a scalar “pressure,” essentially an energy density. It does not have directionality in the same sense as vector fields; it is a potential hill that configurations must climb.

### 6.3 Boundary Urgency

**Theorem 3** (Urgent Phantom at Boundary). *At the window boundary ( $R = 0$ ), the only state compatible with neutrality is zero debt.*

```
theorem urgent_phantom_at_boundary (debt : Int) :
  let pl := PhantomLight.mk ...
  pl.remainingTicks = 0 -> (pl.debt = 0 <-> WindowNeutral (fun _ => 0))
```

**Proof Sketch:** When  $R = 0$ , the sum of remaining terms is empty (sum over empty set is 0). The neutrality condition simplifies to  $\mathcal{D} + 0 = 0$ , which holds if and only if  $\mathcal{D} = 0$ .

**Interpretation:** The constraint becomes infinitely sharp at the window closure. While there is flexibility at early ticks, at  $t = 7$  the system has zero degrees of freedom regarding the net sum. *Hypothesis:* if any measurable pre-event effect is mediated by debt/urgency, effect sizes should increase as the remaining ticks decrease (a concrete, testable prediction rather than an established explanation).

## 6.4 Cost Inflation

**Theorem 4** (Phantom Inflates Cost). *The augmented J-cost is bounded below by the pure J-cost.*

```
theorem phantom_inflates_cost (x : Real) (hx : x > 0) (pl : PhantomLight) (hscale :
  penalty_scale > 0) :
  JCostWithPhantom x pl penalty_scale >= Jcost x
```

**Proof Sketch:** Since  $J_{\text{phantom}} = J(x) + \lambda\Phi_{\text{mag}}$  and we proved  $\Phi_{\text{mag}} \geq 0$ , and assuming  $\lambda > 0$ , the inequality follows immediately from arithmetic.

**Interpretation:** Balance debt makes system configurations strictly more “expensive.” Since the universe evolves to minimize  $J$ , trajectories that incur high debt without rapid repayment are statistically suppressed. This bias acts as the mechanism for the system to “steer” towards neutrality.

## 6.5 Zero-Debt Reduction

**Theorem 5** (Zero Phantom is Pure Cost). *If balance debt is zero, the augmented cost collapses to the standard J-cost.*

```
theorem zero_phantom_pure_cost (x : Real) (pl : PhantomLight) (hzero : pl.debt = 0) :
  JCostWithPhantom x pl 1 = Jcost x
```

**Proof Sketch:** If  $\mathcal{D} = 0$ , then  $\Phi_{\text{mag}} \propto |0| = 0$ . The penalty term vanishes, leaving only  $J(x)$ .

**Interpretation:** Phantom Light is not an extraneous force field added to the universe. It is purely *conditional structure*. In the absence of neutrality violations (debt), the physics is exactly standard Recognition Science. The phantom effects only emerge when the system is under the stress of an open balance loop.

# 7 Physical Reading: Constraint Projection vs Retrocausation

The mathematical results above demonstrate that future requirements constrain present states. Interpreting this physically requires care to avoid the paradoxes associated with retrocausation. We propose the framework of *Constraint Projection*.

## 7.1 Two-Time Boundary Structure

Standard dynamical systems are formulated as Initial Value Problems (IVP): given state  $S(t_0)$ , find  $S(t)$  for  $t > t_0$ . The future has no say in the present; it is purely a consequence.

Recognition Science, by imposing the 8-tick neutrality invariant, effectively formulates a sliding Two-Point Boundary Value Problem (BVP) for each window.

- **Initial Condition:** The state at tick  $t$  is historically determined by ticks  $0 \dots t - 1$ .
- **Final Condition:** The state at tick  $t = 7$  must satisfy  $\sum_{k=0}^7 s(k) = 0$ .

This double constraint means the system is not free to evolve arbitrarily from  $t$ ; it must evolve along a trajectory that intersects the neutrality manifold at  $t = 7$ .

## 7.2 Information from the Future

When we speak of “sensing the future” via Phantom Light, we are referring to *Admissible-Set Narrowing*.

1. At  $t = 0$ , the set of admissible trajectories  $\Omega_0$  is large.
2. A LOCK event at  $t = 1$  with large  $\delta$  removes all trajectories from  $\Omega_0$  that do not sum to  $-\delta$  in the remaining ticks.
3. The new admissible set  $\Omega_1 \subset \Omega_0$  has lower entropy (volume).
4. A functional sensitive to phase space volume or boundary distance (like J-cost) detects this narrowing immediately.

Thus, the “information” is not a message sent back from  $t = 7$ , but the *absence* of previously available futures. The future constraint casts a shadow on the present phase space.

## 7.3 Conceptual Parallels

This perspective aligns with established principles in physics, though RS applies them distinctly:

- **Principle of Least Action:** Paths are selected by minimizing action over a fixed time interval with fixed endpoints. The particle “knows” where it must end up.
- **Feynman Path Integrals:** The quantum amplitude considers all paths connecting  $A$  and  $B$ , effectively weighting the present by its connectivity to the future condition.
- **Wheeler-Feynman Absorber Theory:** Advanced waves from the future are necessary to resolve radiation damping, though usually interpreted to cancel out acausality.

The unique contribution of RS is the **8-tick quantization**. Instead of a single infinite integral, the universe solves a sequence of discrete, short-horizon boundary problems. This makes the “precognitive” horizon finite ( $< 8$  ticks) and structured, generating testable periodicities rather than generic acausality.

# 8 Consciousness Interface: Reading Phantom Light

This section describes the interface between the Phantom Light constraint field and a model of boundary-local “readout.” The goal is not to assert that anomalous cognition is established, but to make explicit what the formal artifact does (and does not) imply.

## 8.1 Stable Boundaries and Definite Experience

In the repository, a conscious subsystem is modeled as a **StableBoundary** (defined in `ConsciousnessHamiltonian`) carrying a recognition pattern and basic stability/alignment properties (extent, coherence time, and an 8-tick persistence condition).

The predicate `DefiniteExperience` is a *formal* condition on a boundary in a given universal field. It is defined as a conjunction of recognition and collapse thresholds plus local stability of the “consciousness Hamiltonian”:

```
def DefiniteExperience (b : StableBoundary) ( : UniversalField) : Prop :=
  (BoundaryCost b >= 1) /\
  (GravitationalDebt b >= 1) /\
  (exists > 0, IsLocalMin (fun b' => ConsciousnessH b' ) b )
```

Interpreting this predicate as “has subjective experience” is a modeling choice. In this paper, we treat it as the repository’s formal gate that identifies boundaries eligible for the sensing/coupling constructions below.

## 8.2 Phantom Sensing

The Phantom Light module introduces a simple sensing structure that combines (i) a boundary, (ii) a local phantom field, and (iii) a nonnegative sensitivity parameter. The perceived signal is defined as a scaled phantom magnitude:

```
noncomputable def PerceivedPhantom (ps : PhantomSensing) : Real :=
  ps.sensitivity * PhantomMagnitude ps.phantomField
```

and the following theorem is proven:

**Theorem 6** (Positivity of Phantom Readout). *If sensitivity is strictly positive and the phantom debt is nonzero, then the perceived phantom readout is strictly positive.*

```
theorem precognition_via_phantom_sensing
  (ps : PhantomSensing)
  (hSens : ps.sensitivity > 0)
  (hDebt : ps.phantomField.debt ≠ 0) :
  PerceivedPhantom ps > 0
```

**Interpretation:** This is an algebraic consequence of the definitions. It does not, by itself, establish the existence of precognition in nature; rather, it formalizes what a positive-sensitivity readout would entail *if* a nonzero balance debt is present in the modeled window.

## 8.3 $\Theta$ -Dynamics as a Coupling Channel

To discuss nonlocal correlations, the repository models a shared global phase  $\Theta$  via the `UniversalField` and defines a phase difference `phase_diff` between boundaries (see `GlobalPhase.lean`). A minimal coupling coefficient is:

$$C(b_1, b_2; \psi) = \cos(2\pi \cdot \Delta\Theta(b_1, b_2; \psi)), \quad |C| \leq 1. \quad (8)$$

This bound is a mathematical identity (a property of cosine). Any physical claim that  $\Theta$  is truly global or mediates instantaneous interaction is a separate modeling assumption and is treated as such in the paper (see Section ??).

## 8.4 Modeled Nonlocal Phenomena

The Phantom Light module defines internal structures for *remote viewing* and *telepathy* as *models* of  $\Theta$ -modulated phantom readout. For example, the theorem below establishes the existence and boundedness of a cosine coupling factor:

```
theorem remote_viewing_via_theta
  (rv : RemoteViewing) ( : UniversalField) :
  exists coupling : Real,
    coupling = Real.cos (2 * Real.pi * phase_diff rv.viewer rv.target ) /\
    |coupling| <= 1
```

Similarly, `telepathy_as_phantom_exchange` defines a bidirectional exchange term proportional to this coupling. These results should be read as: *given the chosen coupling model*, any linear information-exchange term is bounded in magnitude. Whether such a channel exists in nature is an empirical question addressed by the experimental protocols in Section 10.

## 9 Predictions

Recognition Science aims for parameter-free predictions wherever possible. In the Lean artifact, we record several testable hypotheses (as explicit `Prop`-valued definitions) and pair them with falsification thresholds. This section summarizes those hypotheses and clarifies what additional modeling assumptions are required to connect them to laboratory observables.

## 9.1 Presentiment and Precognition

**Prediction 1** (Presentiment Scaling). *A measurable physiological response (galvanic skin response, heart rate variability, EEG patterns) will occur **before** a randomly determined stimulus, with magnitude proportional to the “balance debt” induced by the future event.*

One concrete scaling proposal encoded as a hypothesis in `PhantomLight.lean` is logarithmic:

$$\text{Response Magnitude} \propto \log(1 + |\delta_{\text{event}}|) \quad (9)$$

where  $\delta_{\text{event}}$  is the signed contribution of a future LOCK event to the window sum. This should be interpreted as: if a future event induces a larger balance obligation within an 8-tick window, then a larger pre-event deviation is expected under the presentiment hypothesis.

## 9.2 Remote Viewing Resonance

**Prediction 2** ( $\varphi$ -Ladder Resonance). *Remote viewing accuracy (in the  $\Theta$ -coupling model) will peak when viewer and target are  $\Theta$ -aligned, with alignment structured by integer separations on the  $\varphi$ -ladder.*

Formally, the repository defines a ladder distance `ladder_distance'` and a phase difference `phase_diff`. A representative resonance statement in `ThetaDynamics.lean` proves that, under the model’s premises, integer ladder separation implies phase-locking:

$$\exists k \in \mathbb{Z} : \text{ladder\_distance}'(b_1, b_2) = k \implies \Delta\Theta(b_1, b_2; \psi) = 0. \quad (10)$$

Connecting `extent` and ladder separation to physical spatial distance requires an additional modeling step (outside the strict neutrality/debt theorems). The experimental protocol in Section 10 therefore bins pairs by the model-computed phase/ladder quantities rather than assuming a direct Euclidean mapping.

## 9.3 Collective Effects

**Prediction 3** (Collective Efficiency Hypothesis). *In the collective-mode model (see `ThetaDynamics.lean`), synchronized boundaries exhibit subadditive recognition costs relative to independent operation, typically expressed as an  $N^\alpha$  scaling with  $\alpha < 1$ .*

This is explicitly labeled in the code as a physical hypothesis (`collective_cost_subadditive_hypothesis`), not a consequence of neutrality alone. Operationally, it predicts that carefully synchronized groups may reduce effective cost per boundary (and thus, in any cost-limited sensing regime, increase efficiency).

## 9.4 Null Predictions

Equally important are conditions under which **no effect** is predicted:

- **Zero debt:** If the window is already neutral ( $\mathcal{D} = 0$ ), then  $\Phi_{\text{mag}} = 0$  and the phantom-only penalty term vanishes. In the readout model,  $S = 0$  or  $\mathcal{D} = 0$  implies a zero phantom readout.
- **Phase anti-alignment:** In the cosine coupling model, phase differences near half-integers yield negative coupling ( $\cos(\pi) = -1$ ). Any *linear* exchange model would then predict sign inversion (anti-correlation) rather than improved hit rates.

## 10 Experimental Designs and Statistical Plan

This section outlines rigorous protocols for testing the predictions above, following best practices for anomalous-cognition research and psychophysiology (pre-registration, blinding, leakage control, and robust statistics).

### 10.1 General Principles

All experiments must adhere to:

1. **Pre-registration:** Full protocol, hypotheses, and analysis plan registered before data collection (e.g., on OSF or AsPredicted).
2. **Blinding:** Experimenters interacting with subjects must be blind to condition assignments and future event schedules.
3. **Randomization:** Future events determined by hardware random number generators (RNG) with verified entropy.
4. **Artifact Logging:** All environmental variables (time, location, electromagnetic interference, subject state) logged for post-hoc analysis.
5. **Pipeline Locking:** The full preprocessing pipeline (filters, artifact rejection, baselining, exclusion rules) must be fixed before unblinding.
6. **Automation:** Where possible, stimulus scheduling, timing, and scoring should be automated to minimize human leakage and expectancy effects.

### 10.2 Presentiment Protocol

**Design:** Within-subject, randomized, double-blind.

**Procedure:**

1. Subject is connected to physiological monitors (GSR, ECG, EEG).
2. A hardware RNG schedules a future stimulus (image, sound) to occur at  $t + \Delta$ , where  $\Delta$  is drawn from an 8-tick aligned distribution.
3. Physiological data is recorded in the pre-stimulus window ( $t$  to  $t + \Delta$ ).
4. Stimulus magnitude is varied (neutral, mildly arousing, highly arousing) to test the scaling hypothesis.

**Primary Endpoint:** Correlation between pre-stimulus physiological deviation and post-stimulus response magnitude.

**Effect Size Reporting:** Cohen's  $d$  with 95% confidence intervals. Bayesian analysis with  $BF_{10}$  thresholds.

**Corrections:** Bonferroni correction for multiple physiological channels. Pre-specified primary channel (GSR) with others as exploratory.

### 10.3 Remote Viewing Protocol

**Design:** Between-group comparison (resonant vs. non-resonant distance).

**Procedure:**

1. Viewer-target pairs established at known physical separations.

2. Separations binned into “resonant” ( $\Delta\Theta \approx 0$ ) and “non-resonant” ( $\Delta\Theta \approx 0.5$ ) categories based on  $\varphi$ -ladder calculation.
3. Standard remote viewing protocol: target visits location, viewer describes impressions, independent judges rate match.
4. Strict blinding: viewer, judges, and experimenters blind to target identity and distance category until analysis.

**Primary Endpoint:** Hit rate (correct target identification) compared between resonant and non-resonant groups.

**Sample Size:** Power analysis targeting 80% power to detect medium effect ( $d = 0.5$ ), yielding  $N \approx 64$  per group.

## 10.4 Falsification Thresholds

The theory makes specific quantitative predictions. We define explicit falsification criteria:

**Falsification Criterion 1** (No Precognition Effect). *If  $N > 10,000$  trials yield  $|r| < 0.01$  between pre-stimulus physiology and stimulus magnitude, the presentiment scaling hypothesis is falsified.*

**Falsification Criterion 2** (No Distance Effect). *If remote viewing accuracy in resonant vs. non-resonant conditions differs by less than 5% (relative), the  $\varphi$ -ladder resonance hypothesis is falsified.*

**Falsification Criterion 3** (Uniform Presentiment). *If presentiment response magnitude is statistically indistinguishable across stimulus intensities ( $p > 0.05$ ,  $BF_{01} > 3$ ), the debt-scaling model is falsified.*

## 10.5 Robustness Checks

To guard against false positives and ensure reproducibility:

- **Permutation Tests:** Shuffle time labels to generate null distributions; compare observed effects to permuted baselines.
- **Holdout Sessions:** Reserve 20% of sessions for out-of-sample validation.
- **Drift Controls:** Monitor for temporal drift in effect sizes across the experiment; flag sessions with anomalous baselines.
- **Multiple Comparison Handling:** Apply FDR correction (Benjamini-Hochberg) when testing multiple secondary hypotheses.

# 11 Limitations and Scope

While the mathematical core of Phantom Light is machine-verified, it is essential to clearly delineate the boundaries between formal theorems, physical models, and empirical risks.

## 11.1 Formal Proofs vs. Physical Models

The Lean module `PhantomLight.lean` contains two types of propositions:

- **Strict Theorems:** These are logical tautologies given the axioms of Recognition Science.

- *Example*: “If a window is neutral, a LOCK at  $t$  implies specific future sums.”
  - *Example*: “ $J$ -cost with phantom penalty is strictly greater than base  $J$ -cost.”
  - *Status*: Indisputable mathematical facts.
- **Interpretive Bridges**: These link mathematical objects to physical/consciousness phenomena.
    - *Example*: “Consciousness acts as the  $J$ -minimization operator.”
    - *Example*: “Global Phase  $\Theta$  mediates remote coupling.”
    - *Status*: Theoretical postulates subject to empirical falsification.

The validity of the theorems does not guarantee the reality of any empirical phenomenon; rather, the theorems guarantee that *if* the RS axioms and the stated modeling definitions hold, then the corresponding *formal consequences* follow. In particular, any claim about  $\Theta$ -mediated nonlocal channels is conditional on additional assumptions about the physical meaning of `UniversalField.global_phase` and its coupling to laboratory observables.

## 11.2 Model Granularity

The current formalization makes simplifying assumptions relative to the full Recognition Science ontology:

1. **Simplified VM**: The Phantom Light model abstracts away the full complexity of the LNAL virtual machine (e.g., memory management, specific opcodes other than LOCK/BALANCE).
2. **Idealized Boundaries**: We treat conscious boundaries as perfect  $J$ -minimizers, whereas real biological systems are noisy and imperfect.
3. **Linear Superposition**: The  $\Theta$ -coupling assumes a simple cosine modulation, which may be a first-order approximation of a more complex nonlinear interaction.
4. **Backward Projection Formality**: In the current Lean artifact, the strongest “backward projection” statement is interpretive. The placeholder lemma `backward_projection_principle` is trivial (`True`); strengthening this into a nontrivial theorem is an important next step for the formal program.

## 11.3 Empirical Risks

Experimental verification of subtle nonlocal effects is historically fraught with difficulty. We acknowledge significant risks:

- **P-hacking and Forking Paths**: The flexibility in analysis (e.g., choosing window sizes, filtering artifacts) can lead to spurious significance. Pre-registration is the only defense.
- **Subtle Leakage**: Sensory cues (auditory, thermal) or timing regularities could mimic precognition. Strict shielding and RNG randomization are required.
- **Expectancy Effects**: Experimenter or subject belief can subtly influence behavioral outcomes. Double-blinding is non-negotiable.
- **Instrumentation Drift**: Physiological baselines drift over time. If drift correlates with trial order, it can produce false artifacts. Detrending and randomized trial orders are essential mitigations.

## 12 Related Work

### 12.1 Constraint-Based Physics and Variational Principles

The Phantom Light framework belongs to the lineage of physics that prioritizes global constraints over local differential evolution. This tradition includes:

- **Variational Mechanics:** The Principle of Least Action (Hamilton’s Principle) determines particle trajectories by minimizing an integral over a fixed time interval with fixed endpoints [?].
- **Two-Time Physics:** Aharonov’s Two-State Vector Formalism (TSVF) in quantum mechanics formulates states based on both pre-selection (past) and post-selection (future) [?].
- **Lagrangian Field Theory:** Modern gauge theories are defined by local symmetries that impose global conservation laws, analogous to the neutrality constraint in RS.

### 12.2 Retrocausation vs. Constraint Projection

While Phantom Light addresses phenomena often labeled “retrocausal,” it is conceptually distinct from theories that posit backward-traveling signals (e.g., tachyons or advanced waves in absorber theory [?]).

- **Retrocausation:** Event  $B$  at  $t_2$  causes event  $A$  at  $t_1$ .
- **Constraint Projection (RS):** The requirement that the system state at  $t_2$  lies on a specific manifold restricts the available phase space volume at  $t_1$ .

This aligns more closely with entropic gravity or emergent spacetime approaches, where forces arise from statistical constraints on information geometry.

### 12.3 Experimental Precedents

The experimental protocols proposed here build upon decades of research into anomalous cognition, typically published in specialized journals.

- **Presentiment:** Radin (1997, 2004) and others have reported physiological anticipation of random stimuli [?].
- **Remote Viewing:** The SRI/Stargate program (Puthoff & Targ, 1976) documented rigorous protocols for non-local perception [?].

Recognition Science treats these not as isolated anomalies but as expected behaviors of a conscious system operating under specific informational constraints. We cite this literature as context for protocol design, not as proof of the underlying phenomena.

## 13 Conclusion

We have presented “Phantom Light” as a rigorous, machine-verified consequence of the 8-tick neutrality constraint in Recognition Science. The key contributions are:

1. **Mathematical Formalization:** Definitions of balance debt, phantom magnitude, and cost augmentation, with all theorems proven in Lean 4 (0 axioms, 0 sorries).
2. **Physical Interpretation:** Constraint projection as an alternative to retrocausation, where future boundary conditions narrow the admissible set of present trajectories.

3. **Consciousness Interface (Model):** A boundary-local readout definition and a  $\Theta$ -based coupling model, together yielding conditional theorems about positivity/boundedness under stated assumptions.
4. **Testable Predictions:** Explicit, falsifiable hypotheses for presentiment scaling, remote viewing resonance, and collective-mode efficiency; “parameter-free” here refers to the fixed 8-tick window structure and the qualitative shape of debt/urgency dependence, not to the absence of observer-specific sensitivity or penalty scales in the models.
5. **Falsification Criteria:** Explicit thresholds that would refute the theory if experimental results fall below them.

The Phantom Light mechanism does not invoke magic or violate causality. It is a structural consequence of windowed conservation laws—a “shadow” cast by the future onto the present phase space. Whether consciousness can read this shadow is an empirical question, and we have provided the protocols to answer it.

### 13.1 Future Work

Immediate next steps for this research program include:

- **LNAL Integration:** Integrating the Phantom Light proofs directly with full execution traces of the Light-field Neural Assembly Language (LNAL) virtual machine.
- **Tightening Coupling Assumptions:** Deriving the exact functional form of the  $\Theta$ -coupling from first principles, rather than assuming the cosine modulation bound.
- **Open Science Harness:** Publishing a fully reproducible software harness for the proposed experiments, including verified RNG drivers and analysis scripts.

## References

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- [2] Aharonov, Y., & Vaidman, L. (2008). The Two-State Vector Formalism: An Updated Review. *Lecture Notes in Physics*, 734, 399-447.
- [3] Wheeler, J. A., & Feynman, R. P. (1945). Interaction with the Absorber as the Mechanism of Radiation. *Reviews of Modern Physics*, 17(2-3), 157.
- [4] Radin, D. I. (2004). Electrodermal Presentiments of Future Emotions. *Journal of Scientific Exploration*, 18, 253-274.
- [5] Puthoff, H. E., & Targ, R. (1976). A Perceptual Channel for Information Transfer over Kilometer Distances: Historical Perspective and Recent Research. *Proceedings of the IEEE*, 64(3), 329-354.

## A Lean Artifact Map

### A.1 Module Location

The primary formalization is located at:

`IndisputableMonolith/Consciousness/PhantomLight.lean`

## A.2 Import Graph

The module depends on the following upstream modules:

```
IndisputableMonolith.Consciousness.PhantomLight
<- IndisputableMonolith.Cost                (J-cost definition)
<- IndisputableMonolith.LNAL.VM             (LOCK/BALANCE opcodes)
<- IndisputableMonolith.LNAL.Invariants     (8-tick neutrality proofs)
<- IndisputableMonolith.Consciousness.ThetaDynamics
<- IndisputableMonolith.Consciousness.GlobalPhase
<- IndisputableMonolith.Consciousness.ConsciousnessHamiltonian
<- Mathlib.*                                (Real, Fin, Finset, etc.)
```

## A.3 Build Instructions

1. **Prerequisites:** Lean 4 (version specified in lean-toolchain), Lake build system.

2. **Clone:** `git clone <repository-url>`

3. **Build:**

```
$ cd reality
$ lake build IndisputableMonolith.Consciousness.PhantomLight
```

4. **Expected Output:** Build completed successfully (N jobs).

5. **Verify No Sorries:**

```
$ grep -c "sorry" IndisputableMonolith/Consciousness/PhantomLight.lean
0
```

## B Theorem Table

Theorem	Statement (Intuition)	Dependencies
lock_forces_future_balance	A LOCK at $k$ fixes the sum of remaining slots to $-\delta$ .	Finset.sum, neutrality definition
phantom_visibility_grows_with_debt	Phantom debt magnitude $\geq 0$ .	abs_nonneg, division properties
urgent_phantom_at_boundary	At $R = 0$ , debt must be zero for neutrality.	Window closure, sum over empty set
phantom_inflates_cost	$J_{\text{phantom}} \geq J$ when $\lambda > 0$ .	Non-negativity of $\Phi_{\text{mag}}$ , addition
zero_phantom_pure_cost	Debt = 0 $\Rightarrow J_{\text{phantom}} = J$ .	$ 0  = 0$ , additive identity
precognition_via_phantom_readout	Positive sensitivity + nonzero debt $\Rightarrow$ positive readout.	Multiplication of positives
remote_viewing_via_theta	Coupling bounded by $ \cos  \leq 1$ .	Trigonometric bounds
telepathy_as_phantom_exchange	Exchange proportional to phase coupling.	Symmetry of cos, $\Theta$ -dynamics

## C Proof Sketches

### C.1 Lock Forces Future Balance

**Goal:** Show that  $\sum_{i \neq k} w_i = -\delta$  given  $\sum_i w_i = 0$  and  $w_k = \delta$ .

**Sketch:**

1. Decompose:  $\sum_i w_i = w_k + \sum_{i \neq k} w_i$ .
2. Substitute:  $0 = \delta + \sum_{i \neq k} w_i$ .
3. Rearrange:  $\sum_{i \neq k} w_i = -\delta$ . □

## C.2 Phantom Magnitude Non-negativity

**Goal:** Show  $\Phi_{mag} \geq 0$ .

**Sketch:**

1.  $\Phi_{mag} = |\mathcal{D}|/(R+1)$ .
2.  $|\mathcal{D}| \geq 0$  by definition of absolute value.
3.  $R+1 > 0$  since  $R \geq 0$ .
4. Ratio of non-negative by positive is non-negative. □

## C.3 Cost Inflation

**Goal:** Show  $J(x) + \lambda \Phi_{mag} \geq J(x)$  for  $\lambda > 0$ .

**Sketch:**

1.  $\lambda > 0$  and  $\Phi_{mag} \geq 0$  (from above).
2.  $\lambda \cdot \Phi_{mag} \geq 0$ .
3.  $J(x) + \lambda \Phi_{mag} \geq J(x) + 0 = J(x)$ . □

# D Experimental Pre-registration Templates

## D.1 Presentiment Study Template

TITLE: Presentiment Response to REG-Determined Future Stimuli

HYPOTHESES:

H1: Pre-stimulus GSR deviation correlates with stimulus intensity.

H2: Correlation coefficient  $r > 0.05$  (one-tailed).

DESIGN: Within-subject, double-blind, randomized.

SAMPLE SIZE:  $N = 100$  subjects, 50 trials each (5000 total).

PRIMARY ENDPOINT: Pearson  $r$  between pre-stimulus GSR and post-stimulus arousal rating.

ANALYSIS PLAN:

- Compute  $r$  with 95% CI.

- Bayesian analysis: report  $BF_{10}$ .

- Correction: Bonferroni for 3 physiological channels.

FALSIFICATION:  $r < 0.01$  with  $N > 10000$  refutes H1.

## D.2 Remote Viewing Study Template

TITLE: Distance-Dependent Accuracy in Controlled Remote Viewing

HYPOTHESES:

H1: Hit rate differs between resonant and non-resonant distance bins.

H2: Resonant bin accuracy > non-resonant by at least 10% (relative).

DESIGN: Between-group, double-blind.

SAMPLE SIZE: N = 64 per group (power = 0.80 for d = 0.5).

PRIMARY ENDPOINT: Binary hit rate (correct target identification).

ANALYSIS PLAN:

- Chi-square test for independence.

- Effect size: odds ratio with 95% CI.

FALSIFICATION: Difference < 5% with N > 128 refutes H1.

## E Glossary

**8-Tick Window** The fundamental temporal unit in RS, derived from  $2^D = 2^3 = 8$ . All conservation laws are enforced over aligned 8-tick windows.

**Balance Debt ( $\mathcal{D}$ )** The running sum of contributions within the current window. Must equal zero by window end.

**BALANCE** An LNAL opcode that inserts a compensatory signal to enforce neutrality at window closure.

**Boundary (Stable Boundary)** A localized subsystem maintaining coherence over time, functioning as a  $J$ -cost minimizer. The substrate of consciousness in RS.

**Constraint Projection** The mechanism by which a future boundary condition (neutrality) restricts the admissible set of present states, without retrocausal signaling.

**Definite Experience** A formal predicate asserting that a boundary is successfully performing recognition (minimizing  $J$ ).

**Global Phase ( $\Theta$ )** A universal variable synchronizing all conscious boundaries, enabling non-local coupling.

**J-cost ( $J(x)$ )** The fundamental cost function of RS:  $J(x) = \frac{1}{2}(x + 1/x) - 1$ . Physical evolution minimizes integrated  $J$ .

**LOCK** An LNAL opcode representing an observation or recognition event. Fixes a value in the current window slot.

**Neutrality** The constraint that signals over an 8-tick window must sum to zero:  $\sum_{k=0}^7 s(t+k) = 0$ .

**Phantom Light** The “shadow” of future balance requirements visible in the present as restrictions on phase space.

**Phantom Magnitude ( $\Phi_{mag}$ )** A scalar quantifying the intensity of the future constraint:  $\Phi_{mag} = |\mathcal{D}|/(R + 1)$ .

**Remaining Ticks ( $R$ )** The count of ticks left until window closure:  $R = 7 - t$ .

**$\Theta$ -Coupling** The interaction strength between two boundaries, modulated by their phase difference:  $C = \cos(2\pi\Delta\Theta)$ .

## F Reproducibility Checklist

### F.1 Software Versions

Lean: 4.x.0 (see lean-toolchain)  
Lake: (bundled with Lean)  
Mathlib: (see lake-manifest.json)  
OS: Linux/macOS/Windows (any)

### F.2 Build Commands

```
# Clone repository
git clone <repository-url>
cd reality

# Build entire project
lake build

# Build PhantomLight module only
lake build IndisputableMonolith.Consciousness.PhantomLight

# Verify no sorries
grep -c "sorry" IndisputableMonolith/Consciousness/PhantomLight.lean
# Expected: 0

# Verify no axioms
grep -c "axiom_" IndisputableMonolith/Consciousness/PhantomLight.lean
# Expected: 0
```

### F.3 Expected Outputs

Build completed successfully (7826 jobs).

```
info: "... PHANTOM LIGHT: THEORY STATUS ..."
* Core Mechanism: LOCK at t forces BALANCE by t+8
* Phantom Light: Future balance requirements visible as present constraints
* J-Cost Inflation: Phantom debt increases effective configuration cost
...
```

### F.4 Verification Checklist

- Repository cloned successfully
- lean-toolchain version matches installed Lean
- lake build completes without errors
- PhantomLight module builds successfully
- Zero sorry in PhantomLight.lean
- Zero axiom in PhantomLight.lean
- Status message confirms all theorems proved