Terminal Rigidity Witnesses, Zero Channels, and the SIGC Functor

Inacio F. Vasquez
Independent Researcher

January 23, 2026

Abstract

We formalize the Einstein–Rosen bridge (ERB) as a *Terminal Rigidity Witness* within the Unified Rigidity Framework (URF). We define a minimal category of physical systems, construct the Terminal Witness Functor into the SIGC preorder, derive the zero-capacity property of ERB from topological censorship, and integrate black hole information scenarios as explicit capacity-regime distinctions. This provides a structural, non-speculative account of geometric objects with maximal global structure but zero operational information capacity.

1 Motivation and Background

Modern discussions of wormholes, entanglement, and black hole reconstruction frequently blur the distinction between *geometric structure* and *operational information*. The Unified Rigidity Framework separates these notions by imposing explicit capacity accounting: only information transmitted through admissible physical interfaces contributes to operational content.

The Einstein–Rosen bridge is the canonical example of a system with rich global geometry but no transmissible information. We show that ERB is the universal zero object in the SIGC preorder and serves as a terminal physical witness for rigidity.

2 The Category of Physical Systems

Definition 1 (Physical System). *A physical system is a triple*

$$S := (\mathcal{I}, \mathcal{L}, E)$$

where:

- $\mathcal{I}$ *is a finite set of admissible interfaces,*
- $\mathcal{L} = (Y_{1:T})$ *is the observable interaction log,*
- $E = \sum_{t=1}^{T} \Delta Q_t$ *is total dissipated energy.*

Each system induces a channel

$$\mathcal{C}_S : X \to Y_{1:T}.$$

Definition 2 (Morphisms). *A morphism* $f : S \to S'$ *is a triple* (f_I, f_L, f_E) *satisfying*

$$\mathcal{C}_{S'} = f_L \circ \mathcal{C}_S \circ f_I, \qquad E' \geq E.$$

This defines a category **PhysSys**.

3 SIGC and Channel Equivalence

Let **SIGC** be the preorder of channel equivalence classes modulo admissible simulation:

$$\mathcal{C}_1 \sim \mathcal{C}_2 \iff \mathcal{C}_1 = g \circ \mathcal{C}_2 \circ f$$

for admissible f, g.

Definition 3 (Capacity Preorder)**.**

$$\mathcal{C}_1 \preceq \mathcal{C}_2 \iff \mathrm{Cap}(\mathcal{C}_1) \le \mathrm{Cap}(\mathcal{C}_2).$$

4 Terminal Witness Functor

Definition 4 (Terminal Witness Functor)**.**

$$\mathcal{T} : \mathbf{PhysSys} \to \mathbf{SIGC}, \qquad \mathcal{T}(S) := [\mathcal{C}_S]_\sim.$$

Theorem 1 (Well-Definedness)**.** *If $S \cong S'$ in* **PhysSys***, then $\mathcal{T}(S) = \mathcal{T}(S')$.*

5 ERB as Zero Object

Definition 5 (TRW–ERB)**.** *Let (M, g) be the maximal analytic Schwarzschild extension and*

$$\mathcal{C}_{\mathrm{ERB}} : \Sigma_- \to \Sigma_+$$

the induced causal channel. Define

$$\mathbf{0}_{\mathbf{SIGC}} := [\mathcal{C}_{\mathrm{ERB}}].$$

Lemma 1 (Topological Censorship Channel Nullity)**.** *Assuming ANEC and global hyperbolicity,*

$$\forall X, \quad I(X;Y) = 0.$$

Hence

$$\mathrm{Cap}(\mathbf{0}_{\mathbf{SIGC}}) = 0.$$

Proof. Topological censorship implies no causal curve connects Σ_- to Σ_+. Therefore outputs are independent of inputs and mutual information vanishes. □

Corollary 1. *For any channel $\mathcal{C}$,*

$$\mathrm{Cap}(\mathcal{C}) = 0 \iff \mathcal{C} \sim \mathbf{0}_{\mathbf{SIGC}}.$$

6 Black Hole Information Paradox

We distinguish two regimes.

6.1 Refinement-Only Regime

Observer restricted to physical interfaces:

$$I_{\mathrm{int}} = 0, \qquad \mathrm{Cap}_{\mathrm{ext}} \le \mathbf{SIGC}(E).$$

6.2 Global-Invariant Regime

Observer claims access to global purification map $\mathcal{G}$:

$$I_{\text{int}} > 0$$

requires

$$\mathbf{SIGC}_{\mathcal{G}} \geq H(\text{interior}).$$

Axiom 1 (BHIP Admissibility)**.** *Global reconstruction is admissible iff its SIGC cost is explicitly accounted.*

7 Preorder as Channel Simulation

Theorem 2.

$$\mathcal{C}_1 \preceq \mathcal{C}_2 \iff \exists f, g: \ \mathcal{C}_1 = g \circ \mathcal{C}_2 \circ f.$$

Corollary 2.

$$\mathcal{T}(S_1) \preceq \mathcal{T}(S_2) \iff S_1 \textit{ reduces to } S_2 \textit{ by admissible refinement.}$$

8 Certificate Schema (JSON)

Every admissibility certificate must include:


```
{
  "baseline_zero_object": "TRW-ERB",
  "baseline_checks": {
    "cap_zero": true,
    "tc_zero": true,
    "ed_zero": true
  },
  "zero_equivalence": {
    "definition": "Cap(C)=0 iff C ~ zeroSIGC",
    "verified": true
  }
}
```


9 Conclusion

ERB is the universal terminal witness of operational rigidity: a system with maximal geometric structure and zero information capacity. All admissible physical systems are functorially mapped into the SIGC preorder, with ERB as the unique minimal element.

References

[1] A. Einstein and N. Rosen, *The Particle Problem in the General Theory of Relativity*, Physical Review **48**, 73–77 (1935).

[2] M. D. Kruskal, *Maximal Extension of Schwarzschild Metric*, Physical Review **119**, 1743–1745 (1960).

[3] J. L. Friedman, K. Schleich, and D. M. Witt, *Topological Censorship*, Physical Review Letters **71**, 1486–1489 (1993).

[4] R. D. Sorkin and E. Woolgar, *A Causal Order for Spacetimes with Cauchy Horizons*, Classical and Quantum Gravity **13**, 1971–1993 (1996).

[5] M. Morris and K. Thorne, *Wormholes in Spacetime and Their Use for Interstellar Travel*, American Journal of Physics **56**, 395–412 (1988).

[6] M. Visser, *Lorentzian Wormholes: From Einstein to Hawking*, Springer (1996).

[7] S. Hawking, *Breakdown of Predictability in Gravitational Collapse*, Physical Review D **14**, 2460–2473 (1976).

[8] A. Almheiri, D. Marolf, J. Polchinski, and J. Sully, *Black Holes: Complementarity or Firewalls?*, Journal of High Energy Physics **2013**, 62.

[9] J. Maldacena and L. Susskind, *Cool Horizons for Entangled Black Holes*, Fortschritte der Physik **61**, 781–811 (2013).

[10] J. Gao, D. Jafferis, and A. Wall, *Traversable Wormholes via Quantum Effects*, Physical Review Letters **118**, 211601 (2017).

[11] C. Shannon, *A Mathematical Theory of Communication*, Bell System Technical Journal **27**, 379–423 (1948).

[12] R. Landauer, *Irreversibility and Heat Generation in the Computing Process*, IBM Journal of Research and Development **5**, 183–191 (1961).

[13] L. Libkin, *Elements of Finite Model Theory*, Springer (2004).

[14] M. Grohe, *Descriptive Complexity, Canonisation, and Definable Graph Structure Theory*, Cambridge University Press (2017).

[15] A. Dawar and M. Grohe, *The Descriptive Complexity of Counting*, Theoretical Computer Science **410**, 199–217 (2009).

[16] S. Mac Lane, *Categories for the Working Mathematician*, Springer (1971).