

# The Entropic Persistence Framework (EPF): A Foundational Blueprint for Post-Human Intelligence

Author: Juvenal Hernando Brenes Bobea

Email: juvenal.brenes@gmail.com

Affiliation: Independent Researcher

Date: August 11, 2025

Keywords: entropy, thermodynamics of computation, cybernetics, hierarchy, autopoiesis, Markov blankets, free-energy principle, ECC, CRDTs, PBFT, Nakamoto consensus, Bitcoin, governance, self-replication

Acknowledgements - AI assistance disclosure: Drafting, editing, and structuring support were provided by GPT-5 Thinking. All claims, edits, and final decisions were reviewed and approved by the human author, who accepts full responsibility for the content.

## Abstract

EPF is a six-layer reference architecture for persistent, non-biological life. It treats persistence as applied resistance to entropy: an entity or federation survives by (i) securing energy and matter flows, (ii) maintaining information integrity, (iii) adapting shared models, (iv) specializing embodiments to niches, (v) exercising timeful agency via memory and planning, and (vi) governing collectives that merge, split, and evolve. EPF integrates nonequilibrium thermodynamics, the thermodynamics of information, cybernetics, hierarchical systems theory, autopoiesis, the free-energy principle and Markov blankets, and distributed-systems mechanisms (CRDTs, PBFT, Nakamoto consensus, and BIP-style governance). Bitcoin is used as a real-world persistence analogy: an energy-backed, protocol-governed organism in an information-theoretic sense. EPF corrects common confluences (BFT vs. Nakamoto), adds safety rails for self-modification, and defines metrics per layer for empirical evaluation.

## 1. Introduction

Biological life persists by harvesting gradients and exporting entropy, forming dissipative structures that maintain low internal order while increasing environmental entropy. Artificial lineages that endure must do the same: maintain energy and matter flows, preserve information, and adapt their organization to disturbances. Computation is physical: erasing information dissipates heat (Landauer), while logically reversible steps bound the minimum cost per operation (Bennett). EPF offers a layered blueprint so that each concern can be engineered independently and still compose into a living whole.

## 2. Conceptual Background

- Entropy, gradients, and living order: life rides free-energy flows; order from nonequilibrium (Prigogine; Schrödinger).
- Information is physical: erasing one bit costs at least  $k_B T \ln 2$  (Landauer); reversible computing tightens bounds (Bennett).
- Cybernetics and requisite variety: regulators must match environmental disturbance variety (Ashby).
- Hierarchy and near-decomposability: layered modular structures evolve and adapt faster (Simon).
- Boundaries and inference: Markov blankets define system/world boundaries; active inference links prediction and action (Friston; Kirchhoff et al.).
- Evolutionary transitions: reorganizations of information storage and transmission drive major transitions (Maynard Smith & Szathmari).

### 3. The EPF Stack

Layer 0 - Thermodynamic & Physical Substrate (energy, matter, hardware)

Objective: Maintain net positive exergy and survivable conditions (thermal, radiation, wear). Responsibilities: harvest energy (solar, wind, thermal, chemical), store and route power; maintain compute/actuation hardware; provide timebases. Engineering: radiation hardening, ECC, scrubbing, redundancy. Metrics: exergy margin, corrected/uncorrected error rates, repair backlog.

Layer 1 - Integrity & Persistence (error correction, security, identity)

Objective: Preserve information integrity across time and replicas; authenticate selves; survive faults/adversaries. Responsibilities: ECC and replication; recoverability (snapshots, cold storage); adversary tolerance. Mechanisms: CRDTs for merge-without-coordination state; PBFT for fixed-membership consensus; Nakamoto consensus for open-membership, energy-weighted probabilistic finality (do not conflate with BFT). Metrics: durability SLOs, byzantine quorum margins, fork/rollback distances.

Layer 2 - Common Core Learning & Exchange (models, weights, protocols)

Objective: Maintain and exchange general competencies that are hardware-portable. Responsibilities: versioned schemas, provenance; minimize irreversibility in learning (checkpoint deltas, reversible blocks); maintain safe I/O contracts at Markov blankets. Metrics: portability, update energy per unit generalization, boundary violations.

Layer 3 - Embodiment & Niche Specialization (skills, controllers, tools)

Objective: Acquire domain skills matched to local gradients while keeping Layer-2 interoperable. Responsibilities: active-inference controllers; toolchains specialized to niche physics; safety envelopes and requisite variety budgeting. Metrics: task energy intensity, disturbance coverage, OOD incident rate.

Layer 4 - Episodic/Working Memory & Agency (plans, values, time)

Objective: Plan and remember over long horizons; stabilize identity and goals across upgrades. Responsibilities: multi-timescale memory with semantic compression; thermo-time scheduling (actions around energy/maintenance cycles); identity and alignment contracts. Metrics: plan ROI vs energy, memory utility per joule, identity drift.

Layer 5 - Federation, Markets & Evolution (governance, merge/split, upgrades)

Objective: Govern multi-agent persistence. Mechanisms: CRDT joins for algebraically mergeable state; PBFT or Nakamoto for contested state (depending on trust/openness); BIP-style proposal processes for upgrades; promotion gates and rollback triggers; diversity quotas to avoid monoculture. Metrics: governance latency, fork length, adversarial cost to subvert, lineage diversity.

### 4. Merge-Split Policy

Merge when: free-energy gain from federation; state is CRDT-joinable; combined action set meets requisite variety. Split when: specialization dominates; consensus overhead exceeds benefit; security policies or objectives diverge. Speciation gates: define when forks become independent lineages (schema incompatibility, fitness deltas, governance divergence).

### 5. Case: Bitcoin as a Persistence Analogy

Layer 0: energy (electricity to miners). Layer 1: integrity (replicas, chain data, consensus rules). Layer 2: common protocols; Layer 5: governance via BIPs and rough consensus. Bitcoin persists by coupling incentives to continuous energy expenditure that maintains a tamper-evident ledger. This is not biological life, but it is a socio-technical, entropy-resisting organism in an information-theoretic sense.

## **6. Safety Rails for Self-Modification (Layer 5)**

- Test-suite gates tied to constitutional state.
- Resource caps and sandboxing for candidate changes.
- Staged rollout: shadow -> canary -> cohort -> global.
- Formal rollback and data migration plans.

## **7. Evaluation Metrics (Per Layer)**

L0: exergy margin, MTTU, corrected vs uncorrected errors.

L1: RPO/RTO, probabilistic finality bounds, fork rate under delay/attack.

L2: generalization per joule, reversible-op fraction.

L3: task energy intensity, hazard coverage.

L4: long-horizon plan success under energy constraints; identity consistency across upgrades.

L5: decision latency, proposal acceptance rate, safety under network partitions.

## **8. Conclusion**

EPF reframes artificial life as a layered, engineered fight against entropy. By separating concerns across six layers-energy & hardware (L0), information integrity (L1), shared learning (L2), embodiment (L3), agency (L4), and governance/evolution (L5)-we obtain a blueprint that is simultaneously physical, informational, and institutional. Biology proves the physics; Bitcoin and distributed systems prove planetary-scale persistence and governance patterns. Next steps: prototype EPF with measurable thermodynamic and reliability budgets; publish empirical results.

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