Villnave's Law: A Minimal Persistence Boundary for Complex Systems

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Abstract

Most theories of intelligence, resilience, and adaptation implicitly assume that progress is the primary driver of survival. This paper inverts that assumption. We propose **Villnave's Law**, a minimal persistence boundary that treats continued existence—not optimization—as the primitive quantity. The law defines a scalar persistence number

$$\Omega = \Lambda \chi$$

where Λ represents reinforcement capacity and χ represents internal coherence. Collapse occurs when $\Omega < 1$.

We further define an existence margin

$$M = (\Omega - 1) - \Delta S$$

which captures the surplus or deficit of persistence capacity relative to entropy pressure. Importantly, Villnave's Law is not a controller or recovery mechanism. It is a diagnostic boundary designed to fail honestly under noise, coupling, manipulation, and regime shifts.

We present a comprehensive falsification suite that stress-tests the law under adversarial conditions including entropy accumulation, measurement noise, parasitic coupling, adversarial gaming, regime switching, and comparison against alternative formulations. The results demonstrate that Villnave's Law is not universally survivable—and should not be—but that its failures are sharp, predictable, and structurally meaningful. This positions the law as a foundational viability diagnostic upon which higher-level control primitives may later be constructed.

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1. Introduction

Most modern system theories, spanning artificial intelligence, economics, biology, and infrastructure are implicitly progress-centric. They assume that optimization, learning, growth, or adaptation is the default path to survival.

This assumption is fragile.

Many real systems do not fail because they optimize poorly. They fail because they fall below a viability threshold: coherence erodes faster than reinforcement can compensate, entropy accumulates faster than structure can dissipate, or external pressure overwhelms internal capacity.

Villnave's Law formalizes this boundary explicitly. Rather than modeling how systems improve, it defines when continued existence is no longer possible.

This paper makes no claims about intelligence, optimality, or control. Its sole objective is to define a minimal, falsifiable persistence condition that applies across domains.

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2. Core Law

We define the **persistence number**:

$$\Omega = \Lambda \chi$$

Where:

- $\Lambda \ge 0$ is reinforcement capacity (structure, redundancy, energy access, institutional strength, etc.)
- $\chi \ge 0$ is internal coherence (alignment, integrity, coordination, signal fidelity)

Persistence condition:

$$\Omega > 1 \quad \Rightarrow \quad \text{persistence possible}$$

$$\Omega < 1 \quad \Rightarrow \quad \text{collapse inevitable}$$

Intuitively, no amount of structure (Λ) can compensate for total incoherence ($\chi \to 0$), and no degree of coherence can persist without some reinforcing substrate.

The multiplicative form encodes non-substitutability: both factors are required.

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3. Existence Margin

We define the **existence (persistence) margin**:

$$M = (\Omega - 1) - \Delta S$$

Where:

- $\Delta S \ge 0$ represents total entropy pressure (environmental volatility, noise, decay, adversarial load)

Interpretation:

- $M > 0$: surplus persistence capacity
- $M = 0$: knife-edge viability
- $M < 0$: persistence deficit

The margin does not prevent collapse. It reports proximity to it.

4. What the Law Is (and Is Not)

Villnave's Law is:

- A **viability boundary**
- A **diagnostic scalar**
- A **collapse predictor**

Villnave's Law is **not**:

- A controller
- A recovery algorithm
- A resilience guarantee
- An intelligence model

If the law were robust to noise, coupling, manipulation, or regime shifts, it would be lying. Its purpose is to fail clearly when survival is no longer structurally possible.

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5. Falsification Philosophy

The law is explicitly designed to be breakable.

A persistence law that survives:

- Arbitrary mismeasurement
- Hidden parasitic coupling
- Short-term gaming
- Abrupt regime changes

would be over-optimistic and therefore untrustworthy.

Failure under adversarial conditions is not a flaw—it is the signal.

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6. Falsification Results (Summary)

We subject Villnave's Law to a comprehensive falsification suite including:

- Parameter degeneracy

- Slow and spiked entropy accumulation
- Measurement noise
- Parasitic coupling
- History dependence
- Adversarial Ω-gaming
- Regime switching with hysteresis
- Null random baselines
- Competitor functional forms

Key outcomes:

- Villnave's Law collapses cleanly under noise, coupling, and regime shocks
- Short-term reinforcement spikes cannot mask long-term coherence erosion
- Collapse timing is predictable and interpretable
- Alternative formulations either over-permit survival (additive) or collapse prematurely (min/log)

The law survives exactly where persistence is structurally defensible—and nowhere else.

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7. Conclusion

Villnave's Law reframes survival as a boundary problem rather than an optimization problem. It does not promise resilience. It exposes impossibility.

As such, it is not a solution—but a foundation.

Appendix A — Canonical Falsification Suite

(See `falsification_suite.py` for full reproducible implementation.)

Tests include:

- Degeneracy invariance
- Entropy shape invariance
- Slow entropy poisoning
- Measurement noise

- Parasitic coupling
- History dependence
- Adversarial gaming
- Regime switching
- Null baselines

All tests are adversarial, untuned, and seed-locked.

Appendix B — Why Multiplicative Ω

The multiplicative form uniquely satisfies four required properties:

1. **Zero-Annihilation**
   A system with $\Lambda = 100$, $\chi = 0$ collapses ($\Omega = 0$).
2. **Non-Substitutability**
   Doubling Λ cannot fully compensate for halving χ.
3. **Scale Invariance**
   $(\Lambda = 2, \chi = 0.6)$ and $(\Lambda = 4, \chi = 0.3)$ yield identical Ω.
4. **Predictable Degradation**
   Proportional decay of Λ and χ produces midpoint collapse, unlike additive (delayed) or minimum (premature) forms.

Alternative formulations fail at least one of these properties.

Appendix C — Non-Claims

Villnave’s Law does **not** claim to:

- Maximize intelligence
- Optimize agents
- Prevent collapse
- Replace control theory
- Guarantee safety

It defines when persistence is no longer possible.