

The Entropy Law of Human Systems: A Universal Constraint for Economics, AI, and Institutional Design

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Abstract

Entropy constrains every physical process, yet its role in human-engineered systems is often treated piecemeal. This paper formulates the **Entropy Law of Human Systems (ELHS)**: in the absence of sufficient maintenance energy, entropy within any complex human system rises monotonically, driving drift, fragility, and eventual collapse. The author introduces the law as a gravitational constraint across all human domains, not metaphorically, but as a predictive, falsifiable design principle. The author:

1. Proposes operational entropy proxies for nonmaterial domains
2. Synthesizes supporting theory from economics, information theory, cybernetics, and AI alignment
3. Presents practical design patterns for entropy budgeting in post-AGI economies, institutions, and infrastructure

ELHS reframes entropy as a design parameter with both destructive and constructive potential: much like gravity, entropy can be leveraged—but never eliminated.

This paper builds on a conceptual framework first introduced in a non-academic essay by the author:¹

1 Introduction: A Missing Formalization

To understand the pervasiveness of entropy in human systems, it is useful to compare it directly with gravity. Gravity, while a fundamental force, weakens with distance. A human system like a spacecraft can effectively escape the strong gravitational pull of a planetary body, entering a state of microgravity where its influence becomes negligible for most design purposes. Entropy, by contrast, can never be escaped. Even in deep space—where gravity is minimal—a spacecraft’s internal systems continue to experience entropic drift: batteries degrade, software becomes outdated, decision architectures drift from original conditions. Entropy continues operating within the system regardless of its position in spacetime.

This reveals entropy’s uniquely universal character: it is not just persistent, but unavoidable. Whereas gravity can be functionally circumvented depending on spatial location, entropy follows the system itself. This makes entropy not just a useful analogy, but in many ways a more consistently applicable constraint on human systems than gravity itself.

Despite entropy’s central role in the sciences, its full implications for complex human systems have remained fragmented across disciplines. Thermodynamic entropy constrains physical processes [1], Shannon entropy bounds information transmission [2], and transaction cost economics hints at coordination frictions [3]. Yet no unified framework exists treating entropy as a universal constraint shaping economics, governance, cognition, technology, and AI alignment.

Building on early insights from Georgescu-Roegen [1] about entropy’s relevance to economic processes, this paper proposes that entropy acts like gravity across all human systems: it constantly pulls toward disorder, complexity cost, and misalignment. Any human endeavor that ignores entropy’s gravitational influence courts collapse.

Unlike previous entropy-linked critiques focused on energy depletion or ecological sustainability, the Entropy Law of Human Systems generalizes entropy as a gravitational design constraint on all human-built complexity—informational, cognitive, institutional, and computational.

¹Goosen, D.J. (2025). *If I’m Wrong About AGI and UBI Has to Happen*. Published on Substack, April 2025. <https://djgoosen.substack.com/p/if-im-wrong-about-agi-and-ubi-has>

2 Formal Statement: The Entropy Law of Human Systems

Entropy functions like a gravitational pull on all complex human systems—an ever-present tendency that must be resisted or leveraged. It is omnipresent, scales with system complexity, and operates predictably, tending toward increased disorder, misalignment, and inefficiency unless actively countered through maintenance, feedback, and renewal. Like gravity, entropy can be temporarily resisted, strategically leveraged, but never eliminated.

Corollary

Any system of sufficient complexity must invest energy (cognitive, economic, informational, organizational) to offset entropic drift. Failure to do so guarantees system decay or collapse over time.

Metaphor

Just as engineers use gravitational potential energy (e.g., in hydroelectric dams) to perform useful work, designers of human systems can harness entropic effects (e.g., feedback loops, innovation cycles) to achieve strategic goals—but must constantly manage the underlying entropic pull.

Consider air.

Moving air—wind—is an entropic phenomenon: energy diffusing across pressure gradients, increasing microscopic disorder as it pushes the system toward macroscopic equilibrium. When we erect turbines, we intercept that gradient—extracting structure from the dispersal. We do not stop entropy; we harness its slope.

Entropy increases microscopic disorder—not as an absolute measure, but as a delta between states: structure diffuses, gradients flatten, and usable energy decays. We rarely measure the atoms themselves—we infer entropy from the system’s decreasing ability to maintain distinction or perform work.

Consider a single breath of air. A human inhales, and there is oxygen in that breath—enough to keep them conscious, to keep the system of the body running. But oxygen makes up only a small fraction of the air around them; most of what they breathe is nitrogen. The reason they survive is because all the atoms in the air are moving constantly, chaotically, bouncing off each other in every direction—high entropy. That very disorder is what makes every breath probabilistically sufficient for life.

And yet—and this is the key—there is no physical law that guarantees any given breath will contain enough oxygen for the organism which depends on it. There is no formal reason for a human to expect consistency in any one inhalation. Life persists because entropy, in its randomness, creates reliable statistical patterns over time and space.

We survive not only in spite of entropy, but also sometimes because its nature aligns with our needs, while we also continually evolve to work within its constraints. That alignment is fragile. It is emergent. And every breath is a momentary wager that the system hasn’t broken down—yet.

In both cases—wind power and breathing—we don’t escape entropy. We use its flow to temporarily outrun its consequences.

The universe itself is entropic. Its inflationary expansion isn’t order spreading—it is structure being stretched farther against a growing backdrop of decay.

Thus, to exist is to also be in motion. And to maintain coherence in that motion—across time, across systems, across identity—is the core human and physical challenge.

Measuring the Mass of a Kilogram

One striking illustration of entropy’s omnipresence is found in the history of the International Prototype of the Kilogram (IPK)—a platinum-iridium artifact once used as the global standard for defining mass. Despite being stored in a climate-controlled vault and handled with extreme care, the IPK was found to be mysteriously losing atoms over time. That is, the very object humanity relied on to define “one kilogram” was subject to physical degradation—an entropic process embedded in its mere existence.

This drift was not symbolic. It was measurable. It eventually led to the redefinition of the kilogram based on a fixed value of Planck’s constant, decoupling the standard from any decaying physical reference.

This episode illustrates that entropy is not a metaphor—it is a persistent constraint, even in our most carefully maintained and conceptually stable systems.

This transition—from a physical artifact to an abstract, universal constant—did not remove entropy from the system. It merely relocated it, trading material drift for mathematical abstraction. We can no longer hold the kilogram in our hands, because entropy made that act of trust unsustainable.

The redefinition of the kilogram using Planck’s constant reflects a broader truth about human systems under entropy: when physical reference points succumb to decay, abstraction becomes the only stable refuge. The Planck constant—an invariant of quantum physics—offered a way to preserve coherence not by fixing matter, but by anchoring measurement in a fundamental, mind-accessible constant. In this sense, the move from artifact to abstraction was not just a scientific improvement; it was an existential strategy. Sometimes, the only way humans can outrun entropy in the physical world is to retreat into stable mathematical frameworks—into the mind itself.

Measuring the Length of a Second

A similar case arises in our definition of time. Historically, the second was defined based on the rotation of the Earth—specifically, $\frac{1}{86,400}$ of a mean solar day. However, due to tidal friction and other planetary-scale entropic processes, Earth’s rotation is gradually slowing and exhibits irregular variations. As a result, the astronomical second became increasingly unreliable as a precise reference.

To preserve the accuracy and consistency required for modern science and technology, the second was redefined in 1967 using the cesium-133 atom: the duration of 9,192,631,770 cycles of radiation corresponding to a specific atomic transition. This shift from planetary to atomic reference reflects a broader pattern: as entropy destabilizes natural baselines, human systems must retreat into higher-fidelity abstractions to preserve coherence.

Any claim that a human system can function indefinitely without overcoming entropy is structurally incoherent. Entropy is not a force one occasionally resists—it is the default trajectory. Survival is a deviation from entropy, and that deviation must be continuously earned. Systems that appear “stable” are simply better at hiding or externalizing their negentropic work.

It is, to the author, self-evident that all human systems—being embedded within the physical universe—are unavoidably subject to entropy. This is not an abstract constraint but a structural condition of existence. Any system that persists must either resist entropy directly or exploit entropic flows for functional gain.

Falsifiability and Testability

The Entropy Law of Human Systems can be tested by observing drift, decay, or collapse in real-world systems lacking explicit entropy management strategies. Case studies might include organizational failure rates, AI alignment drift over long time horizons, or increasing software fragility in unmaintained codebases. Conversely, systems that implement continuous feedback and renewal mechanisms can be empirically studied for resilience and longevity, providing comparative validation of the law.

Formal Expression of the Law

Let $S(t)$ represent the entropy of a human system over time, and $M(t)$ be the system’s net maintenance energy (including feedback, oversight, cognitive bandwidth, etc.). Then for any system of complexity $C > C_0$ (some minimum irreducible complexity threshold), the Entropy Law asserts:

$$\frac{dS(t)}{dt} > 0 \quad \text{if} \quad M(t) < M^*(C)$$

Where:

- $\frac{dS(t)}{dt}$ is the time derivative of entropy — its rate of increase
- $M^*(C)$ is the minimum entropy-offsetting maintenance function required for complexity C
- If $M(t) < M^*(C)$, entropy increases monotonically, leading to drift, fragility, or failure
- If $M(t) \geq M^*(C)$, entropy growth can be arrested or locally reversed

This formulation provides a falsifiable framework: researchers can model, simulate, or empirically test whether systems with underbudgeted maintenance predictably experience decay or misalignment — and whether increasing $M(t)$ restores stability.

3 Evidence Across Domains

3.1 Economics and Institutional Design

- Georgescu-Roegen (1971) framed economic processes as irreversible transformations constrained by entropy.
- Institutional theorists [3] recognize that organizations drift toward homogenization and loss of informational richness without periodic rejuvenation.
- Geoffrey West (2017) [4] shows scaling in companies leads to bureaucratic entropy that ultimately limits lifespan.

3.2 Cognitive Systems and Information Processing

- Wiener (1948) and Ashby (1956) [5, 6] observed that biological and cognitive systems constantly resist entropic drift through feedback and adaptation.
- Rational inattention models [7] and studies of cognitive decline frame human attention and memory limits as entropic effects.

3.3 Software Systems

- Lehman’s Laws of Software Evolution (1974) [8] demonstrate that evolving software systems naturally increase in entropy (complexity, fragility) unless refactored.

3.4 AI Alignment and Value Drift

- AI alignment researchers [9] recognize that misalignment over time is not an accident but a fundamental entropy-like drift requiring continual human intervention.

4 Practical Implications

4.1 Post-AGI Economic Models

- Deflationary UBI schemes, automation-driven prosperity, and resource management must budget for entropy—in trust systems, pricing mechanisms, and incentive architectures.

4.2 Institutional Resilience

- Constitutions, governance models, and corporate charters must embed entropic maintenance loops: feedback, transparency, rejuvenation cycles.

4.3 AI Governance and Alignment

- AGI systems must be designed with continuous correction mechanisms, ethical feedback loops, and system-level entropy monitoring to prevent drift from original aligned objectives.

4.4 Technology and Infrastructure

- Complex technological systems (e.g., global cloud infrastructures, decentralized ledgers) require ongoing entropy budgeting: redundancy, refactoring, stress-testing.

5 Conclusion: Entropy as the Universal Design Constraint

Entropy is not a metaphor in complex human systems—it is the effective gravitational condition of them. It defines the slope all systems operate on. Just as no engineer would design a structure without accounting for gravitational load, no economist, policy designer, or AI architect should attempt to build or scale systems without explicitly budgeting for entropy.

This paper does not argue that entropy is a barrier to be feared, but rather a substrate to be designed against—and sometimes through. It is a predictable force. It demands maintenance energy, yes—but also offers opportunities for resilience, renewal, and even generative transformation when understood structurally.

The Entropy Law of Human Systems calls for a design paradigm shift: from frictionless idealism to entropy-aware pragmatism. In an AGI-enabled future of unprecedented scale, speed, and system interdependence, the question is no longer *if* entropy applies—but *how precisely* it must be measured, managed, and leveraged to avoid collapse and realize sustained prosperity. The law is not merely descriptive; it is prescriptive. It tells us: no complexity without cost, no structure without drift, no system without gravity.

Our laws of economics, governance, and technology have long pretended to be gravity-free. But entropy, like the expansion of the universe, is the default slope of time. Designing for the long term means aligning with this truth—not denying it.

Everything in the physical universe trends toward equilibrium—toward evenness, rest, and diffusion. This is entropy’s nature: not random destruction, but the quiet erasure of distinction. Temperature gradients flatten. Pressure equalizes. Energy disperses.

Human systems survive by intercepting that flattening. We build turbines to catch the wind. We breathe to keep the chemical gradient alive. We build meaning, hierarchy, structure—interruptions in entropy’s smooth curve.

And the great design choice before every human system is this:

*Will we overcome entropy—or harness it?
Will we resist the flattening—or channel its slope into structured work?*

6 Limitations and Future Work

This paper introduces a unifying theory of entropy across human systems, but several boundaries remain. First, edge cases may arise where AGI systems simulate low-entropy conditions without continuous human feedback. Second, some analog systems or biologically inspired architectures may develop adaptive forms of entropy regulation that challenge the strict gravitational analogy. Third, while entropy’s relevance to digital and institutional decay is clear, its application to deeply physical or ecological systems (e.g., planetary-scale feedback loops) needs further articulation.

Future work should develop formal metrics for entropy in non-material systems, explore entropy-resilient governance architectures, and rigorously simulate entropy management in AGI alignment scenarios. Testing and modeling entropy drift in large language models, financial markets, and planetary-scale infrastructure may further refine the universality claim of the Entropy Law of Human Systems.

On the Illusion of Stable Institutions

Apparent counterexamples to the ELHS—such as millennia-old religions or enduring institutions—are not exceptions, but confirmations of the law. Their longevity reflects sustained, often invisible, negentropic inputs: doctrinal reinterpretation, ritual practice, community enforcement, language evolution, and active transmission. Even religious laws degrade when unpracticed, as physical media deteriorates and oral interpretation diverges over time. These systems persist not because they defy entropy, but because they invest in resisting it. ELHS predicts that without these forms of maintenance, such systems would inevitably fragment or dissolve.

Author’s Note

This paper was developed through a process of large language model-augmented formalization. All core insights, original syntheses, and theoretical framings—including the Entropy Law of Human Systems

(ELHS), and the deflationary UBI model—originated from the author. Large language models (LLMs) were used not to generate ideas, but to refine, pressure-test, and formalize the author’s ideas. To the author’s knowledge, no existing literature in peer-reviewed or preprint archives has articulated this specific synthesis—the Entropy Law of Human Systems—as a falsifiable, mathematically framed, cross-domain constraint integrating thermodynamic, cognitive, economic, institutional, and AI alignment entropy under a single predictive model.

Further Reading

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