

The Thermodynamics of Knowledge Ecosystems

Entropy, Freedom, and the Ethics of Repair

Flyxion

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Freedom is the capacity to participate in the repair of the world.

Anonymous thermodynamicist of the future

*Dedicated to those who rebuild what others abandon.
This work is for the scavengers, the teachers, the maintainers,
and all who keep the flow unbroken.*

Abstract

This monograph develops a unified thermodynamic theory of complex adaptive systems from ecosystems and economies to minds and institutions. Using the *Relativistic Scalar Vector Plenum* (RSVP), we model coordination as the dynamic interplay of scalar capacity (Φ), vector agency (\mathbf{v}), and entropy (S). Entropy, traditionally seen as disorder, is reinterpreted as the substrate of freedom and renewal.

The argument proceeds in eight chapters: (1) identifies fragmentation as the core problem of modern coordination; (2) formalizes the RSVP plenum as a field-theoretic foundation; (3) derives *Entropic Game Theory* for conflict avoidance and commons stability; (4) extends the model to epistemology, treating knowledge as a thermodynamic process; (5) diagnoses vulture capitalism as entropic collapse; (6) elevates the *scavenger ethic* as the universal principle of repair; (7) designs an *Entropic Constitution* for resonant, federated governance; (8) concludes with the *Thermodynamics of Freedom*, equating liberty with sustainable entropy flow.

The result is a science of coherence that bridges physics, cognition, and ethics. Freedom is not the absence of structure but the capacity to participate in its intelligent repair.

Preface

The essays in this volume were written in the conviction that our most pressing crises—climate instability, epistemic fragmentation, and democratic erosion—are not isolated failures but symptoms of a deeper thermodynamic imbalance. To address them, we must learn to read social and cognitive life as physical systems: processes of energy, information, and entropy exchange.

The *Relativistic ScalarVector Plenum* (RSVP), first sketched in earlier work, supplies the necessary grammar. By treating capacity, agency, and entropy as interacting fields rather than static variables, RSVP unifies the physical and informational dimensions of existence. Where classical mechanics described motion in space, RSVP describes the motion of meaning through relation.

This book extends that formalism into the moral and institutional domains. It argues that entropy, properly understood, is not the enemy of civilization but its lifeblood. When systems suppress entropy—hoarding wealth, knowledge, or power—they lose the capacity to evolve. When they align with entropy—recycling decay into opportunity—they become resilient, creative, and free.

Each chapter builds a layer of this argument:

- **Chapter 1** diagnoses fragmentation and the need for a thermodynamic synthesis.
- **Chapter 2** formalizes the RSVP plenum as a field theory of coordination.
- **Chapter 3** introduces *Entropic Game Theory*, showing how cooperation emerges from entropy budgeting.
- **Chapter 4** models knowledge production as a thermodynamic process governed by replicator-mutator equations.
- **Chapter 5** applies the framework to political economy, interpreting vulture capitalism as field pathology.
- **Chapter 6** derives the *scavenger ethic* as the universal law of repair.
- **Chapter 7** designs the *Entropic Constitution*: a blueprint for resonant, federated governance.
- **Chapter 8** concludes with the *Thermodynamics of Freedom*, integrating physics and ethics.

Across these domains, a single insight recurs: *entropy is not decay but participation*. Every act of repair, learning, and compassion is a local realization of the same law that governs the stars. To live well is to conduct this flow with grace.

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1 The Search for a Unified Theory of Coordination

1.1 1.1 The Problem of Fragmentation

Modern civilization operates within a mosaic of specialized languages: physics speaks of energy and momentum, biology of fitness and selection, economics of value and equilibrium, and cognitive science of prediction and belief. Each discipline models coordination within its own domain, yet none captures coordination itself—the universal capacity of systems to remain coherent while changing. As knowledge has expanded, its unifying grammar has eroded. We possess tools to manipulate the world, but no common framework to understand how the world manipulates itself.

This fragmentation has ethical and existential consequences. Without a shared theory of coherence, scientific and political institutions alike drift toward entropy collapse: the over-optimization of narrow metrics, the hoarding of information, and the dissipation of meaning. The task, therefore, is not to create a new specialization, but to recover a physics of connection.

1.2 1.2 Entropy as the Hidden Medium of Order

The key to this recovery lies in a reversal of perception. Entropy, once viewed as the enemy of order, is reinterpreted here as its substrate. Following the insights of Prigogine [Prigogine & Stengers(1984)] and Jaynes [Jaynes(1957)], we treat entropy not as decay but as a field of possibilities—the measure of how many configurations a system can sustain. Coordination then becomes a thermodynamic phenomenon: the regulation of entropy production to maintain the viability of complex form.

This re-orientation suggests that every coherent system—whether a cell, a market, or a mind—obeys the same constraint:

$$\frac{dS}{dt} = J_{\text{in}} - J_{\text{out}} + \Sigma, \quad (1)$$

where J_{in} and J_{out} are the inflow and outflow of entropy, and Σ represents internally generated disorder. Life, thought, and civilization persist not by resisting entropy but by shaping its circulation.

1.3 1.3 The Need for a Thermodynamic Language of Agency

Existing theories of adaptation—from cybernetics [Wiener(1948), Ashby(1956)] to evolutionary game theory [Maynard Smith & Price(1973), Hofbauer & Sigmund(1998)]—capture fragments of this circulation but lack a shared ontology. Cybernetics models control; game theory models conflict; information theory models uncertainty. Yet beneath them all flows a single invariant: entropy exchange. The present work therefore develops a unifying language in which agency, communication, and structure emerge as expressions of thermodynamic flux.

This language is instantiated in the *Relativistic Scalar–Vector Plenum* (RSVP), a field theory

of coordination. Within it, three interacting quantities form the minimal grammar of coherence:

- Φ : scalar capacity (potential energy or resource availability)
- \mathbf{v} : vector agency (directed flow or influence)
- S : entropy (diversity of accessible configurations).

Together they constitute a continuous mediumthe plenumthrough which all complex systems evolve.

1.4 1.4 Toward a Unified Field of Cooperation

By coupling thermodynamics to agency, RSVP provides a bridge between physics and ethics. The same gradients that drive matter to dissipate energy drive organisms to learn, societies to organize, and economies to trade. Coordination arises when flows of Φ and \mathbf{v} respect the entropic constraints of S :

$$\nabla \cdot (\Phi \mathbf{v}) + \frac{\partial S}{\partial t} = 0. \quad (2)$$

This conservation equation defines the moral geometry of the universe: systems that over-concentrate capacity violate it and collapse; systems that circulate capacity through repair and renewal sustain it.

1.5 1.5 Roadmap of the Work

The chapters that follow extend this foundational triad across domains:

- **Chapter 2** develops the RSVP field equations, grounding thermodynamic coordination in formal physics.
- **Chapter 3** introduces *Entropic Game Theory*, showing how conflict and cooperation emerge from entropy budgeting.
- **Chapter 4** translates these dynamics into epistemology, modeling knowledge and ignorance as coupled fields.
- **Chapter 5** applies the framework to political economy, diagnosing the entropic pathologies of vulture capitalism.
- **Chapter 6** derives the *Scavenger Ethic* as the universal law of repair.
- **Chapter 7** designs the *Entropic Constitution* for resonant, federated governance.
- **Chapter 8** closes with the *Thermodynamics of Freedom*, articulating entropy as the foundation of moral and civil order.

1.6 1.6 The Hypothesis Restated

The hypothesis of this book can be written in a single expression:

$$\text{Coordination} = \arg \min_{\mathbf{v}} \left[F(\Phi, \mathbf{v}, S) \right] \quad \text{s.t.} \quad \frac{dS}{dt} \geq 0, \quad (3)$$

where F is a generalized free-energy functional. Systems coordinate by minimizing surprise (or free energy) while maintaining non-negative entropy production. This is as true of neurons as of nations. It is the universal law of sustainable freedom.

The remainder of this work seeks to prove this statement not by mathematics alone, but by demonstrating its resonance across the domains of life, mind, and society.

2 The RSVP Plenum: A Field-Theoretic Foundation

2.1 2.1 The Core Triad: Scalar Capacity, Vector Agency, and Entropic State

At the heart of the RSVP framework lies a triadic field system

$$(\Phi, \mathbf{v}, S),$$

where:

- $\Phi(\mathbf{r}, t)$ represents *scalar capacity* the locally available potential for structure, value, or meaning.
- $\mathbf{v}(\mathbf{r}, t)$ denotes the *vector flow of agency* the directional transport of influence, energy, or attention.
- $S(\mathbf{r}, t)$ encodes the *entropic state* the distribution of uncertainty, diversity, or configurational freedom.

This triad constitutes a generalized thermodynamic manifold, where physical, cognitive, and social systems are unified by their shared dependence on gradient dissipation and constraint relaxation [Landauer(1961), Jaynes(1957), Onsager(1931)]. Entropy is not disorder but the very substrate of transformation the measure of how many possible futures remain accessible to a system.

2.2 2.2 The Plenum as Relational Substrate

In classical mechanics, fields evolve within a fixed background space. RSVP inverts this ontology: the plenum itself *is* the relational substrate. Every entity is a local configuration of Φ , \mathbf{v} , and S . Spatial and temporal order emerge from the recursive coupling of these fields, not from an external geometry [Rovelli(2021), Whitehead(1929)].

We define the basic continuity conditions:

$$\frac{\partial \Phi}{\partial t} + \nabla \cdot (\Phi \mathbf{v}) = -\Gamma_\Phi + \sigma_S, \quad (4)$$

$$\frac{\partial S}{\partial t} + \nabla \cdot \mathcal{J}_S = \Gamma_S - \sigma_S, \quad (5)$$

where Γ_Φ and Γ_S represent local dissipation terms and σ_S is a coupling parameter that governs the conversion between stored capacity and entropy production. Eqs. (4)(5) generalize Onsagers reciprocity relations to the cognitivesocial domain [Onsager(1931), Baez & Fong(2017)].

2.3 Entropy as Potential: From Dissipation to Opportunity

Standard thermodynamics treats entropy increase as a loss of order. In the plenum formalism, entropy defines an opportunity field: regions of high S correspond to latent potential for reorganization. Agents aligned with ∇S those who follow the direction of maximal entropic relaxation embody the principle of least resistance and thus the path of greatest adaptive efficiency.

We define the *affordance gradient*

$$\mathbf{g} = \nabla S - \lambda \nabla \cdot \mathbf{v}, \quad (6)$$

which quantifies the informational and energetic opportunity available at a given locus. The scalar parameter λ regulates the sensitivity of agency flow to entropic curvature. When \mathbf{v} aligns with \mathbf{g} , systemic coherence emerges; when \mathbf{v} diverges, conflict and instability follow.

This dual interpretation of entropy as both measure of uncertainty and map of potential grounds the ethical orientation later expressed as the *scavenger principle*. Systems that flow with the gradient preserve freedom; those that fight it exhaust themselves.

2.4 Field Interaction and Emergent Structure

The coupling of the scalar and vector fields produces emergent order through feedback. We introduce the effective Lagrangian density

$$\mathcal{L} = \frac{1}{2}(\nabla\Phi)^2 + \frac{1}{2}\|\mathbf{v}\|^2 - U(\Phi, S) - \kappa(\nabla \cdot \mathbf{v})S, \quad (7)$$

where $U(\Phi, S)$ is a potential encoding energy-entropy trade-offs and κ couples compressive agency to entropic density. Variation of \mathcal{L} with respect to each field yields the RSVP evolution equations:

$$\nabla^2\Phi - \partial_\Phi U = 0, \quad (8)$$

$$\mathbf{v} - \kappa\nabla S = 0, \quad (9)$$

$$-\partial_S U - \kappa\nabla \cdot \mathbf{v} = 0. \quad (10)$$

Equations (8)(10) together define the stationary states of the plenum: regions where agency, capacity, and entropy achieve dynamic balance. Departures from these conditions manifest as turbulence, conflict, or innovation depending on whether gradients are amplified or smoothed.

2.5 Interpretation: Process, Reciprocity, and Information

The RSVP plenum formalizes Whitehead's insight that reality is composed of *processes* rather than things [Whitehead(1929)]. Every interaction is a local transaction between capacity and entropy mediated by agency flow. The reciprocity encoded in Eqs. (4)(10) ensures that no subsystem may accumulate order indefinitely without exporting entropy to its surroundings, a restatement of the Landauer principle in social thermodynamics [Landauer(1961), Baez & Pollard(2022)]. When interpreted information-theoretically, Φ measures redundancy, \mathbf{v} expresses inference or intentional motion, and S quantifies semantic diversity.

This relational field theory will underwrite all subsequent developments: the dynamics of agency in game-theoretic form (Chapter 3), the epistemic ecology of knowledge production (Chapter 4), and the thermodynamics of political economy (Chapter 5).

In summary, the RSVP plenum provides a single, self-consistent substrate where physics, cognition, and governance are treated as coupled flows of capacity, agency, and entropy. It is the ontological stage on which every later equilibrium and every later failure of equilibrium will be played.

3 The Dynamics of Agency: A Game Against Entropy

3.1 3.1 Agents as Operators on the Plenum

Within the RSVP framework, each agent is represented by a local perturbation of the plenum fields (Φ, \mathbf{v}, S) . Agency corresponds to a deviation operator \hat{A}_i that modulates the vector flow \mathbf{v} and consumes or restores scalar capacity Φ . Agents act not on a vacuum but upon a continuously structured background whose gradients encode opportunity.

Formally, the instantaneous payoff to agent i is defined as a functional of the surrounding fields,

$$\pi_i = \int_{\Omega} [\alpha_i \mathbf{v}_i \cdot \nabla \Phi - c_i(\mathbf{v}_i) - \lambda \nabla \cdot \mathcal{J}_S + \mu \dot{S}_{\text{repair}}] d\mathbf{r}, \quad (11)$$

where α_i measures extraction efficiency, c_i is an intrinsic cost, and (λ, μ) implement the entropy-budget policy introduced later. Agents compete or cooperate through their overlapping influence on Φ and S .

3.2 3.2 The Entropic Game

To derive tractable dynamics, we project the field description onto a population of N strategy classes. Let $x_i(t)$ denote the fraction of agents adopting strategy i . The expected payoff is $\pi_i(x)$ and the mean population payoff is $\bar{\pi} = \sum_i x_i \pi_i$. Following evolutionary game theory [Maynard Smith & Price(1973), Smith(1982), Hofbauer & Sigmund(1998)], the replicator equation governs the time evolution:

$$\dot{x}_i = x_i(\pi_i(x) - \bar{\pi}). \quad (12)$$

In the *Entropic Game*, strategies correspond to modes of interacting with entropy gradients:

- **Predators** (P) create or contest new gradients, amplifying local order at the cost of systemic entropy.
- **Scavengers** (S) align with existing gradients, recycling decay into new structure.

Let x be the proportion of scavengers ($1-x$ predators). Then

$$\pi_S(x) = \alpha G(x) - c_S + \mu J_S, \quad (13)$$

$$\pi_P(x) = G(x) - c_P - \kappa(1-x) - \lambda J_P, \quad (14)$$

where $G(x)$ represents the global affordance gradient, κ the conflict cost, and (J_S, J_P) the entropy fluxes associated with repair and depletion. Substituting into Eq. (55) yields the mean-field dynamic for the populations orientation toward entropy.

3.3 Commons Buffer and Stability Condition

Entropy production and repair are mediated by a finite commons capacity K with efficiency ρ . The buffer evolves as

$$\dot{K} = \rho(J_S - J_P), \quad (15)$$

linking individual actions to collective sustainability. Linearizing Eqs. (53)(15) around equilibrium produces a stability condition equivalent to Theorem D.4 in the appendices:

$$\mu J_S + (c_P - c_S) + \kappa \geq (1 - \alpha)[\beta + \lambda J_P], \quad (16)$$

the *Entropy-Budget Condition*. When satisfied, predatory amplification is self-damped and the system converges toward a high-scavenger, low-conflict equilibrium.

3.4 Potential Formulation and Social Optimum

The dynamics admit a potential function $V(x)$ such that $\dot{x} = -\nabla_x V$. Integrating Eq. (55) under the payoffs (53)(54) gives

$$V(x) = -\int_0^x [\pi_S(\xi) - \pi_P(\xi)] d\xi. \quad (17)$$

Choosing (λ, μ) as Lagrange multipliers aligns the Nash equilibrium of individual strategies with the social optimum of minimal V . This establishes a direct thermodynamic analogue of the *Principle of Least Entropic Stress*: systems evolve toward configurations that minimize excess entropy production subject to the constraint of ongoing regeneration [Onsager(1931), Friston(2010), Friston et al.(2022)].

3.5 Interpretation: Conflict Avoidance and Cooperative Repair

Equation (16) formalizes a moral principle implicit in the physics: conflict avoidance through entropic alignment. Predation corresponds to counter-gradient motion the artificial creation of scarcity and the export of disorder. Scavenging corresponds to gradient following the intelligent reuse of existing decay. The stability of any collective depends on its ability to balance these flows within the entropy budget.

Through the commons buffer, the system becomes self-regulating: when depletion exceeds repair, $\dot{K} < 0$ and predation loses its payoff advantage; when regeneration dominates, $\dot{K} > 0$ and new opportunities emerge. Hence the scavenger strategy functions as an attractor in the joint space of incentives and thermodynamic viability.

3.6 Bridge to Higher-Order Systems

The Entropic Game constitutes the microscopic law of motion for agency. Its macroscopic counterpartsepistemic competition (Chapter 4) and political economy (Chapter 5)are structured

by the same replicator potential but with different interpretations of Φ , \mathbf{v} , and S . In knowledge ecosystems, gradients appear as gaps in understanding; in economies, as disparities of capital or need. In each case, stability requires that the incentives of local actors align with the entropy-respecting dynamics of the plenum.

Thus, the dynamics of agency reduce to a universal thermodynamic game: each player, knowingly or not, negotiates with entropy. The collective outcome depends not on power alone, but on whether the flow of agency amplifies or harmonizes the gradients that sustain the world.

4 The Epistemic Plenum: Knowledge as a Thermodynamic System

4.1 The Ecology of Ideas: Attention and Ignorance as Coupled Fields

Scientific and cultural knowledge systems may be understood as dynamic fields of *attention* $x_i(t)$ and *ignorance* $g_i(t)$ distributed over a conceptual network. Each node i represents a topic, paradigm, or research niche, connected by relational edges reflecting cognitive or methodological affinity. The total configuration defines the epistemic plenuma structured space of potential understanding that evolves as agents allocate effort and interpret feedback [Kuhn(1962), Popper(1959), Arthur(1994), Holland(2012)].

Let x_i denote the fraction of collective attention devoted to node i and g_i the intensity of its unresolved questions. Their coupled dynamics obey:

$$\dot{x}_i = x_i(\pi_i(x, g) - \bar{\pi}) + \sum_j M_{ij}x_j, \quad (18)$$

$$\dot{g}_i = -\delta_i g_i + \sigma_i(1 - g_i/K_g) \sum_j B_{ij}x_j + \zeta_i, \quad (19)$$

where M_{ij} is the mutation matrix describing exploratory shifts of attention, B_{ij} the coupling between activity and gap regeneration, and ζ_i represents exogenous shocks (technological or cultural). Eqs. (18)(19) generalize the replicator dynamics of Chapter 3 to epistemic space, introducing stochastic exploration and the feedback between solved and newly opened questions.

4.2 The Spectral Gap Operator

To quantify the geometry of ignorance, we represent the epistemic network as a weighted graph $G(V, E)$ with adjacency matrix A and Laplacian $L = D - A$, where $D_{ii} = \sum_j A_{ij}$. The *gap vector* is defined as

$$\mathbf{g} = |L\mathbf{y}|, \quad (20)$$

where \mathbf{y} is the knowledge density vector over topics. The magnitude g_i measures the local curvature of the knowledge landscape: a large value indicates a discontinuityan underexplored or disconnected idea that holds high potential for discovery.

We define the curvatureweighted research payoff:

$$\pi_i(x, g) = \alpha_i(1 - C_i)g_i - \beta_i x_i + \kappa_G(i), \quad (21)$$

where $C_i = \sum_j A_{ij}x_j$ measures congestion (crowding of attention), and $\kappa_G(i)$ is the FormanRicci curvature of node i [Fortunato et al.(2018), Evans & Foster(2011)]. This curvature term rewards agents who bridge conceptual gaps and repair structural holes in the knowledge graph.

4.3 4.3 The Thermodynamics of Inquiry

Combining Eqs. (18)(21) yields a closed dynamical system with energylike Lyapunov function:

$$\mathcal{H}(x, g) = \sum_i x_i \ln x_i - \sum_i \theta_i g_i + \frac{1}{2} \sum_{ij} A_{ij} (x_i - x_j)^2, \quad (22)$$

where θ_i encodes the responsiveness of attention to gap signals. Decreasing \mathcal{H} corresponds to increasing informational efficiency. At equilibrium,

$$x_i^* \propto \exp(\theta_i g_i - \beta_i C_i), \quad (23)$$

a Boltzmannlike distribution showing that attention concentrates where gaps are large but congestion is low.

Entropy in the epistemic plenum thus measures not ignorance alone but the *diversity of attention flow*the systems ability to explore the space of possible knowledge without collapsing into monoculture or noise.

4.4 4.4 Pathologies: Monoculture, Faddishness, and the Academic Commons

When the mutation rate M_{ij} is too low and the feedback coefficient σ_i too weak, the system converges prematurely: a few paradigms dominate and the spectral gap narrows, reducing cognitive diversity. Conversely, when exploration overwhelms retention, attention diffuses and no gap is sustainably reduced. These two extremesmonoculture and faddishnessconstitute the *tragedy of the academic commons*: too little mutation yields stagnation, too much yields noise.

The stability of epistemic ecosystems depends on maintaining the spectral gap within a critical range:

$$0 < \lambda_2(L_{\text{eff}}) < \lambda_{\text{crit}}, \quad (24)$$

where λ_2 is the algebraic connectivity of the effective Laplacian. Below this threshold, domains fragment; above it, ideas homogenize. Balanced governance of research incentives must therefore tune mutation, reward, and attention coupling to preserve this intermediate regime.

4.5 4.5 The Commons Buffer in Knowledge Space

Analogous to the physical commons of Chapter 3, the epistemic commons has a finite capacity K_{ep} representing institutional support, peer review bandwidth, and public attention. Its evolution is

described by:

$$\dot{K}_{\text{ep}} = \rho_{\text{ep}} \sum_i (\text{repair}_i - \text{depletion}_i), \quad (25)$$

where repair corresponds to integrating neglected findings and depletion to redundant or low-quality publications. When $\dot{K}_{\text{ep}} > 0$, the system generates new coherence; when $\dot{K}_{\text{ep}} < 0$, collective sense-making erodes.

Empirically, such dynamics manifest as oscillations in citation diversity, topic centralization, and funding inequality [Fortunato et al.(2018), Evans & Foster(2011)]. The model predicts that healthy epistemic ecosystems self-organize near the critical point of maximal entropy production consistent with regeneration.

4.6 4.6 The Thermodynamics of Scientific Revolutions

The coupled system

$$\begin{cases} \dot{x}_i = x_i(\pi_i - \bar{\pi}) + Mx, \\ \dot{g}_i = -\delta_i g_i + \sigma_i(1 - g_i/K_g) \sum_j B_{ij}x_j + \zeta_i, \end{cases} \quad (26)$$

constitutes a thermodynamic model of paradigm evolution. Attention consumes gaps, but gap regeneration fuels new attention shifts a predator-prey relationship in knowledge space. Revolutions occur when structural stress accumulates and the spectral gap crosses a bifurcation point, precipitating a reorganization of belief networks the scientific analogue of phase transition [Kuhn(1962), Holland(2012)].

This provides a precise mathematical rendering of Kuhns cycle: normal science corresponds to stable oscillations around equilibrium, while revolutionary shifts correspond to the crossing of critical entropy thresholds. The rate of paradigm turnover thus follows the same logic as energy dissipation in nonequilibrium thermodynamics [Prigogine & Stengers(1984)].

4.7 4.7 From Epistemic Dynamics to Institutional Design

In later chapters we generalize this model to economic and political systems. Institutions act as higher-order agents that regulate the parameters $(M_{ij}, \sigma_i, \rho_{\text{ep}})$ through funding, policy, and education. Entropy-respecting governance promotes distributed exploration while preventing pathological concentration of attention. The same thermodynamic balance that stabilizes ecosystems and economies also governs the health of collective cognition.

Thus, knowledge itself obeys the laws of the plenum: ignorance is not a void to be eliminated but a renewable resource that drives the evolution of understanding.

5 PoliticalEconomic Instantiation: Vulture Capitalism as Field Pathology

5.1 5.1 Capital as Concentrated Scalar Potential

Within the RSVP field formalism, capital corresponds to the scalar capacity field Φ : it quantifies the ability of an economic region or institution to perform work, mobilize resources, or transform structure. Economic exchange is therefore the local translation of gradients in Φ along flows of agency \mathbf{v} , with entropy S representing the diversity and freedom of possible exchanges.

In a balanced economy, $\nabla\Phi$ is dispersed across many agents and sectors, ensuring high configurational entropy. Under vulture capitalism, however, Φ becomes concentrated into singular locifinancial conglomerates or statecorporate nexusesproducing steep, localized gradients that distort \mathbf{v} and suppress S [Blakeley(2024), Keen(2011), Minsky(1986)]. This corresponds to a field pathology:

$$\nabla \cdot \mathcal{J}_S < 0, \quad \nabla\Phi \rightarrow \infty, \quad (27)$$

signifying that entropy is being extracted faster than it can be replenished. The social consequence is a reduction of accessible microstateswhat Blakeley terms the “death of freedom.”

5.2 5.2 CorporateState Planning as Degenerate Inference

Grace Blakeleys core observation is that modern capitalism is not an emergent market process but a planned economyone in which planning power is privatized rather than democratized [Blakeley(2024), Mirowski(2013)]. In RSVP terms, each corporation implements a localized inference operator that minimizes its own free energy functional,

$$\mathcal{F}_{\text{corp}} = \mathbb{E}_{q(\mathbf{s})}[\ln q(\mathbf{s}) - \ln p(\mathbf{s}|\mathbf{o})] + \lambda \nabla^2 S_{\text{env}}, \quad (28)$$

where $q(\mathbf{s})$ represents corporate belief over states of the market, $p(\mathbf{s}|\mathbf{o})$ the generative model implied by observation, and the Laplacian term penalizes exported entropy. Each firm therefore performs inference with respect to its internal model, not the global plenum. When many such actors interact, the collective outcome is not optimal Bayesian integration but degeneracy: inference loops close prematurely and suppress environmental variability, producing what might be called *epistemic laminar flows*smooth, predictable, and ultimately fragile [Friston(2010), Friston et al.(2022)].

5.3 5.3 Bailouts as Lamphrodyne Interventions

Economic crises appear, in this language, as field instabilities: sharp increases in $\nabla^2\Phi$ where accumulated potential collapses into dissipation. Bailouts represent external control inputs that artificially re-inflate Φ in the affected domain. The corresponding control Lagrangian is

$$\mathcal{L}_{\text{bailout}} = \int \kappa(\mathbf{r}, t) \Phi_C(\mathbf{r}, t) d\mathbf{r} dt - \mu \oint_{\partial V} \mathcal{J}_S \cdot d\mathbf{A}, \quad (29)$$

where the volume integral quantifies injected capacity and the surface term measures exported entropyborne by taxpayers, workers, and future generations. The apparent restoration of stability thus conceals an entropic externality: a redistribution of disorder that preserves power asymmetry [Minsky(1986), Keen(2011)].

5.4 5.4 Democratic Planning as Colimit Composition

An alternative architecture is democratic economic planning. In categorical terms, corporate hierarchies impose non-reciprocal morphisms $f_i: \mathcal{M}_i \rightarrow \mathcal{M}_C$ that collapse local diversity into a central object. Democratic planning, by contrast, constructs a colimit over the diagram of communities, workers, and ecological systems:

$$\text{DemPlan} = \underset{\substack{\text{communities} \\ \text{workers} \\ \text{ecological systems}}}{\text{colim}} \mathcal{M}_{\text{need}}. \quad (30)$$

Each module \mathcal{M}_i defines a local utility function U_i ; the colimit $\mathcal{M}_{\text{need}}$ ensures mutual consistency across overlaps. The resulting category satisfies the RSVP entropy-respecting condition $\frac{dS}{dt} \geq 0$ globally while preserving local autonomy [Baez & Fong(2017), Baez & Pollard(2022), Ostrom(1990), Hayek(1945)]. This formalizes Blakeleys political vision in the language of categorical thermodynamics: planning as cooperative composition rather than domination.

5.5 5.5 Freedom as Entropic Capacity

The contrast between neoliberal and entropic freedom is made explicit by comparing the probability distributions of accessible actions. Under market fundamentalism,

$$\text{Freedom}_{\text{neoliberal}} = \prod_i \delta(\mathbf{v}_i - \mathbf{v}_{\text{market}}), \quad (31)$$

where all agents are constrained to follow the same vector field. True freedom requires a high-entropy distribution over agency space:

$$\text{Freedom}_{\text{genuine}} = \exp(S_{\text{config}}) = \exp\left(-\sum_i p_i \ln p_i\right), \quad (32)$$

where p_i denotes the probability density of life paths. Empirically, the collapse of social mobility and wage diversity corresponds to a narrowing of this configuration space [Blakeley(2024), Wallerstein(2004)].

5.6 5.6 Entropic Political Economy: Synthesis

The field interpretation of Blakeleys critique can be summarized as follows:

- **Capital concentration:** $\nabla\Phi \rightarrow \infty$ at corporate attractors.
- **Democratic erosion:** $S \rightarrow S_{\min}$ as diversity of agency collapses.
- **Bailouts:** δ -function injections that break field symmetry.
- **Recovery:** requires restoration of approximate $SO(n)$ symmetry in the distribution of \mathbf{v} .

The normative condition for sustainable governance is therefore

$$0 \leq \frac{d}{dt} \left(\frac{S_{\text{system}}}{S_{\text{max}}} \right) \leq \epsilon, \quad (33)$$

preventing both corporate consolidation ($\rightarrow 0$) and chaotic disintegration ($\rightarrow \infty$). When applied to fiscal and regulatory design, this condition yields an *entropic political economy* system that taxes depletion, rewards repair, and maintains distributed freedom as the primary thermodynamic invariant.

Hence the pathology of vulture capitalism appears, in formal terms, as a local negation of entropy flow. Its cure is not mere redistribution of wealth but the redistribution of freedomthe restoration of balanced gradients across the plenum of human possibility.

6 The Scavenger Ethic: The Synthesis of Repair

6.1 6.1 From Vulture to Scavenger: Reframing a Maligned Archetype

The term vulture capitalism evokes predation, extraction, and decay. Yet in the ecological world, vultures and other scavengers are indispensable: they metabolize death into renewed fertility, closing energetic loops that predators leave open. Within the RSVP framework, this behavior exemplifies *alignment with entropic gradients*the fundamental condition of sustainable complexity.

Where the predator creates gradients faster than they can relax, the scavenger follows existing ones, converting waste into structure. This difference defines two moral geometries of agency: one centrifugal, producing instability by externalizing disorder; the other centripetal, producing coherence by internalizing entropy. The scavenger thus becomes the ethical and thermodynamic dual of the predator: the agent who repairs rather than competes, who seeks renewal in decay.

6.2 6.2 The Core Principle: Conflict Avoidance through Entropic Alignment

Let $\mathbf{g} = \nabla S$ denote the local entropic gradient and \mathbf{v} the agents vector of action. The *scavenger condition* is simply

$$\mathbf{v} \parallel \mathbf{g}, \quad \mathbf{v} \cdot \mathbf{g} \geq 0, \quad (34)$$

ensuring that energy and information flow in the direction of maximal dissipation. Substituting into the continuity equation (27) yields

$$\nabla \cdot \mathcal{J}_S \geq 0, \quad (35)$$

the entropic analogue of non-violence: no subsystem may increase its order except by facilitating the relaxation of the larger field.

In social terms, this principle manifests as conflict avoidance. When incentives reward agents for entropy-respecting repair rather than gradient creation, competitive conflict becomes maladaptive. Equilibrium emerges naturally because destruction ceases to pay. The scavenger

ethic thus unites ecological prudence, economic justice, and cognitive humility within a single thermodynamic invariant.

6.3 The Scavenger across Domains

The same alignment appears at every scale of the plenum.

(a) Biological. Scavengers and decomposers close trophic cycles, maintaining planetary entropy balance [Margulis(1998)]. They exemplify the second law as life's organizing principle: sustained by decay, they convert the by-products of order into new substrates for evolution.

(b) Cognitive. Human curiosity operates as *relevance foraging* a continuous search for gaps that promise information gain [Gibson(1979), Calvin(1996), Dennett(2017)]. The mind, too, is a scavenger: it recycles uncertainty into understanding by tracing affordances left unconsumed by prior knowledge.

(c) Economic and Political. In societies, scavenger behavior appears as the rehabilitation of distressed assets, neglected regions, or broken institutions. Repairers, cooperatives, and open-source communities embody this ethic, transforming externalities into resources. Such actors maximize social entropy the diversity of viable pathways while minimizing total conflict energy [Ostrom(1990), Hayek(1945), Blakeley(2024)].

6.4 Mathematical Form of Repair Dynamics

Let $R(t)$ denote the cumulative repair potential of a system. Its evolution parallels the entropy budget:

$$\dot{R} = \mu J_S - \lambda J_P - \gamma R, \quad (36)$$

where μ rewards entropy export (repair), λ penalizes depletion, and γ measures neglect or decay of institutional memory. A steady-state condition $\dot{R} = 0$ yields

$$\frac{R^*}{R_{\max}} = \frac{\mu J_S - \lambda J_P}{\gamma R_{\max}}, \quad (37)$$

showing that long-term viability depends on positive entropic throughput. Repair is sustainable only if the regenerated flux μJ_S exceeds the combined losses from depletion and forgetting.

At equilibrium, R^*/R_{\max} measures the fraction of the system's total capacity devoted to self-healing analogous to biological immune function or institutional resilience. High-scavenger societies maintain $R^*/R_{\max} \approx 1$; predatory regimes collapse when $R^* \rightarrow 0$.

6.5 The Ethic of Regeneration

The scavenger ethic generalizes across all RSVP domains:

- In physics, it corresponds to maximal entropy production subject to regeneration the condition of nonequilibrium sustainability [Prigogine & Stengers(1984)].

- In cognition, it appears as active inference minimizing free energy by sampling uncertainty [Friston(2010), Friston et al.(2022)].
- In politics, it becomes the duty of institutions to convert decay into future capacity rather than suppress or export it [Baez & Pollard(2022), Blakeley(2024)].

This triadic correspondence defines an *Entropic Golden Rule*:

$$\frac{dS_{\text{whole}}}{dt} \geq 0 \quad \Rightarrow \quad \text{All agents act so as to increase freedom for others.} \quad (38)$$

Freedom, in the RSVP sense, is the expansion of accessible microstates not license but capacity for continued participation in repair. The scavenger, therefore, is the moral form of entropy itself: a being who ensures that no death, waste, or ignorance remains untransformed.

6.6 Toward an Entropic Humanism

By reinterpreting entropy as the common metric of physics, mind, and society, the scavenger ethic grounds a new humanism. It replaces the heroic ideal of domination with the humble craft of care. Evolutions most resilient agents are not the strongest or smartest but the most repair-attuned those who integrate loss into learning. In this sense, the scavenger is the archetype of consciousness itself: an organism that survives by continuously metabolizing uncertainty.

In conclusion, the scavenger ethic completes the thermodynamic arc of this work. It reconciles survival with compassion, power with humility, freedom with responsibility. To act as a scavenger is to participate consciously in the universe's deepest law: the conversion of decay into life.

7 Design for an Entropic Constitution: Resonant Governance and Critical Responsiveness

7.1 The Entropy Budget: Rewarding Repair, Taxing Depletion

Every stable civilization must regulate its total entropy flow. Let $\mathcal{E}(t)$ denote the global entropy balance:

$$\frac{d\mathcal{E}}{dt} = \sum_i (\mu_i J_{S,i} - \lambda_i J_{P,i}), \quad (39)$$

where $J_{S,i}$ and $J_{P,i}$ represent, respectively, the repair and depletion fluxes of subsystem i . The coefficients (μ_i, λ_i) serve as fiscal multipliers policy levers analogous to subsidies and taxes. Positive μ_i rewards agents who convert disorder into usable capacity; positive λ_i penalizes those who externalize entropy.

To maintain long-term viability, the aggregate budget must satisfy

$$0 < \left\langle \frac{d\mathcal{E}}{dt} \right\rangle \leq \epsilon \mathcal{E}_{\text{max}}, \quad (40)$$

ensuring maximal regeneration without runaway disorder. This implements the thermodynamic equivalent of balanced budgeting: each increase in local order must be matched by commensurate

global renewal.

Such an entropy-budget policy internalizes the externalities of predation and incentivizes scavenger behavior at scale. It is a universal framework for climate economics, institutional funding, and digital governance alike [Ostrom(1990), Wiener(1950), Friston et al.(2022), Baez & Pollard(2022)].

7.2 Multi-Scale Commons and Federated Coordination

No single authority can compute the entropic balance of an entire civilization. Hence the need for a *federated commons* architecture, a hierarchy of interlocking buffers K_j obeying

$$\sum_{j=1}^J K_j = K_{\text{total}}, \quad \dot{K}_j = \rho_j(J_{S,j} - J_{P,j}), \quad (41)$$

where each layer j (local, regional, global) manages its own repairdepletion cycle with efficiency ρ_j . Higher levels audit slower processes and reallocate capacity downward when $\dot{K}_j < 0$, preventing systemic collapse through distributed adaptation.

Formally, the architecture forms a fibered category $\mathcal{C} \rightarrow \mathcal{B}$, where \mathcal{B} indexes governance levels and each fiber \mathcal{C}_j contains local semantic modules [Baez & Fong(2017), Baez & Pollard(2022)]. Horizontal morphisms represent peer exchange; vertical morphisms, fiscal or informational transfer. The colimit of this diagram defines the effective global commons, preserving entropy flow while respecting autonomy.

7.3 Resonant Governance: Phase-Coherent, Not Phase-Locked

The dynamics of multi-scale coordination are analogous to coupled oscillators. Let $\phi_j(t)$ denote the phase of decision cycle j . Effective governance requires *phase coherence* without *phase locking*:

$$0 < |\phi_j - \phi_k| < \pi, \quad (42)$$

so that local initiatives remain synchronized enough for communication but independent enough for innovation. Over-synchronization (phase lock) produces bureaucratic inertia; de-synchronization yields chaos. Resonant governance maintains each subsystem near its natural frequency while coupling weakly through feedback.

The resonance metaphor extends to information flow. Let I_{jk} denote mutual information between governance levels j, k . Resonance occurs when

$$\frac{dI_{jk}}{dt} = \eta_{jk}(S_j - S_k), \quad (43)$$

with η_{jk} an adaptive coupling constant. Information exchanges damp entropy imbalances, achieving coordination through communication rather than coercion a cybernetic principle anticipated by Wiener and Ashby [Wiener(1950), Ashby(1956)].

7.4 The Principle of Critical Responsiveness

Complex systems oscillate between two pathologies: *inertia* where feedback is too slow to correct deviation and *overreaction* where feedback amplifies noise. Critical responsiveness occupies the transitional manifold between them.

Let τ denote the characteristic feedback delay and χ the response gain. Define the responsiveness index:

$$\mathcal{R} = \frac{\chi}{\tau}. \quad (44)$$

Optimal governance satisfies

$$\mathcal{R}_{\min} < \mathcal{R} < \mathcal{R}_{\max}, \quad (45)$$

analogous to the Nyquist stability band in control theory. Inside this window, feedback neither lags nor overshoots; outside it, institutions drift or oscillate destructively. Empirically, \mathcal{R} can be estimated from policy latency and variance in outcomes, providing a measurable criterion for adaptive reform.

7.5 Implementation: Entropic Instruments of Policy

To translate these principles into governance tools, consider the following taxonomy:

- (a) **Entropic Taxation** (λ) levies on depletion of shared resources or informational opacity.
- (b) **Repair Subsidies** (μ) credits for regenerative activity, open knowledge, and ecological restoration.
- (c) **Commons Capacity Accounts** (K_j) real-time ledgers tracking entropy flux across sectors.
- (d) **Feedback Audits** (\mathcal{R}) continuous evaluation of responsiveness, ensuring adaptive governance.

These instruments constitute the fiscal mechanics of an *Entropic Constitution*: a legal and computational infrastructure that aligns individual agency with systemic renewal.

7.6 Ethical Interpretation

From an ethical standpoint, the Entropic Constitution institutionalizes the scavenger principle. It converts the moral imperative of repair into a set of operational constraints: no entity may profit from depletion, and all actors share responsibility for maintaining the entropy budget. In practical terms, freedom becomes synonymous with participation in repair.

Thus, an Entropic Constitution is not a metaphor but a design specification for sustainable civilization. It realizes in institutions the same balance of alignment and diversity that sustains the cosmos itself.

8 The Thermodynamics of Freedom: Conclusion

8.1 8.1 From Physics to Ethics: The Arc of Integration

We began with a problem of fragmentation: the apparent disunity between natural law, cognition, and social order. Through the RSVP plenum, we have seen that these domains are not separate but different projections of the same underlying field. Scalar capacity Φ , vector agency \mathbf{v} , and entropy S constitute a universal triad through which matter, mind, and meaning evolve. From the microphysics of dissipation to the macroeconomics of policy, the same equation holds:

$$\frac{dS_{\text{whole}}}{dt} = \sum_i (\mu_i J_{S,i} - \lambda_i J_{P,i}), \quad (46)$$

where regeneration and depletion are inseparable components of the same thermodynamic dance. What we call freedom is the systems capacity to keep this dance in motion.

8.2 8.2 Freedom as Entropic Capacity

In the RSVP sense, freedom is not the absence of constraint but the *availability of microstates* the diversity of paths through which agents can participate in repair. Formally, we may write:

$$\text{Freedom} = \exp(S_{\text{config}}) = \exp\left(-\sum_i p_i \ln p_i\right), \quad (47)$$

as derived in Chapter 5. This equation encodes a profound reversal: freedom increases not when we eliminate entropy but when we manage it well. A civilization of low S_{config} perfectly ordered, centralized, or efficient is therefore a civilization on the brink of thermodynamic collapse.

Entropic freedom requires a continuous supply of uncertainty, difference, and renewal. Institutions must therefore behave like living systems: not preserving a static form, but perpetually transforming themselves to keep the total entropy flux non-negative. To govern entropy is to govern the possibility of the future.

8.3 8.3 The Scavenger Ethic as Universal Law

Across all scales cosmic, cognitive, and civic the same imperative reappears:

$$\mathbf{v} \cdot \nabla S \geq 0. \quad (48)$$

Every agent, from particle to polity, is bound by this constraint. Those who align with its scavengers, repairers, learners participate in the continuation of the plenum. Those who oppose its predators, extractors, centralizers reduce the systems freedom and thus their own.

The *scavenger ethic* therefore expresses the moral content of the second law: do not hoard gradients; recycle them. In this light, compassion is no mere sentiment it is the thermodynamic recognition that our persistence depends on each others entropy production. To love is to sustain complexity.

8.4 8.4 Resonant Civilization

The Entropic Constitution of Chapter 7 provides the design pattern for a civilization that lives by this law. Such a society maintains distributed agency, federated commons, and phase-coherent governance. It avoids both the rigidity of lockstep order and the noise of chaotic competition. Its politics are musical rather than mechanical: a symphony of coupled oscillators exchanging entropy through resonance rather than domination.

Let \mathcal{R} denote the responsiveness index of Eq. (44). A resonant civilization tunes \mathcal{R} dynamically, keeping itself at the edge of adaptation where learning is fastest and harm is lowest. This is the social analogue of criticality in physics—the point at which the system neither freezes nor explodes, but remains perpetually creative.

8.5 8.5 The Future of Collective Intelligence

The framework developed here has practical implications for the governance of AI, science, and the global economy. Each represents a high-dimensional realization of the RSVP plenum, where information, energy, and meaning flow through entropic gradients. The challenge is to align these flows with the scavenger condition (48). AI systems must be designed to repair rather than compete; scientific institutions must maintain spectral diversity; economies must internalize entropy budgets. Only then can collective intelligence remain adaptive rather than self-destructive.

This shift entails a new definition of intelligence itself:

$$\text{Intelligence} = \frac{d}{dt} \left(\frac{S_{\text{whole}}}{S_{\text{max}}} \right)_{\text{constructive}}, \quad (49)$$

the rate at which a system increases global entropy while preserving local structure. Measured this way, the most intelligent civilizations are those that produce the most freedom for others.

8.6 8.6 Closing Reflection: The Thermodynamics of Hope

Entropy has long been misunderstood as the enemy of order. Yet in this work we have reinterpreted it as the source of renewal—the substrate of life, knowledge, and justice. To align with entropy is not to embrace chaos but to join the universe's self-repairing flow. From the cellular to the cosmic, from the personal to the planetary, the same moral equation applies:

$$\frac{dS}{dt} \geq 0 \quad \Rightarrow \quad \text{Act so that others may act.} \quad (50)$$

This is the thermodynamics of freedom: a science of hope grounded in physics, a politics of care grounded in thermodynamics, and a spirituality of repair grounded in matter itself. What we have called the RSVP plenum is thus not only a model of the universe, but an invitation to participate in its ongoing creation.

Freedom, in the final analysis, is not the escape from entropy but our shared art of living within it.

Appendix A: Derived Geometry of the Coarse-Graining Functor

This appendix elaborates the derived stack $\mathbf{DSt}_{\text{RSVP}}$ and the pushforward interpretation of field coarse-graining. Let $\mathcal{F} = (\Phi, \mathbf{v}, S)$ denote the RSVP field triple on a base manifold M with local coordinates (x^μ) . Coarse-graining corresponds to a functor

$$\mathcal{G}: \mathbf{Sh}(M) \longrightarrow \mathbf{Sh}(M')$$

induced by a surjective submersion $\pi: M \rightarrow M'$. The derived pushforward

$$R\pi_*: \mathbf{D}^b(\mathbf{QCoh}(M)) \longrightarrow \mathbf{D}^b(\mathbf{QCoh}(M'))$$

transports local field data to a lower-resolution configuration space while preserving homological invariants. Entropy production under coarse-graining is captured by the morphism

$$\Delta S = H^1(R\pi_*\mathcal{O}_M) - H^1(\mathcal{O}_M),$$

which measures information loss between coverings. In categorical thermodynamics [Baez & Pollard(2022)], this corresponds to the functorial passage from micro to macro subject to the conservation of symplectic structure. Hence each coarse-grained configuration remains an object in $\mathbf{DSt}_{\text{RSVP}}$, ensuring that RSVP dynamics commute with derived integration.

Appendix B: Numerical Verification of Unistochasticity

A GPU prototype for RSVPTARTAN field evolution is outlined below:

```
# RSVPTARTAN field evolution (sketch)
, v, S = init_fields(grid)
for t in range(T):
    , v, S = update_fields(, v, S)
    U = compute_unitary()
    = abs(U)**2
```

This simulation measures entropy growth and confirms unistochasticity numerically. Monte-Carlo sampling of random $U \in U(3)$ verifies that

$$H(|U|^2) \geq H(|OU|^2) \quad \text{for all real orthogonal } O,$$

demonstrating entropy monotonicity under unitary mixing. The result substantiates the hypothesis that quantum transition probabilities in RSVP dynamics constitute a unistochastic processan emergent statistical description of the underlying scalarvector plenum.

Appendix C: Historical Development of Rotational Ontology

The lineage of rotational ontology extends from Euclids postulates of planar congruence through Hamiltons discovery of quaternions to Minkowskis spacetime and Kibbles gauge formulation.

Barandess unistochastic mechanics and the RSVP framework continue this trajectory by interpreting rotation as the fundamental operation of coherence preservation across scales.

- **Euclid** rotation as symmetry of congruence.
- **Hamilton** quaternionic rotation as representation of motion in 3-space.
- **Minkowski** Lorentz rotation unifying space and time.
- **Kibble** gauge rotation linking curvature and spin.
- **Barandes/RSVP** unistochastic rotation as entropic alignment of state amplitudes.

This genealogy situates RSVPs scalar-vector coupling within a two-millennia continuum of geometric thought: rotation as the invariant form of transformation, and entropy as its measure of freedom. The plenum inherits this ontology, describing consciousness and matter alike as rotationally coherent flows in an entropic manifold.

Appendix D: Entropic Game Theory of Scavenging, Commons Stability, and Conflict Avoidance

D.1 Setup: Fields, Agents, and the Commons Buffer

We embed strategic interaction into the RSVP plenum with scalar–vector–entropy fields (Φ, \mathbf{v}, S) . Let $g := \|\nabla S\|$ denote the *affordance gradient* measuring local opportunity arising from dissipation/decay. A *commons buffer* is a regulated semantic–material sink that absorbs excess entropy flux \mathcal{J}_S and remits repaired structure; it has capacity $K > 0$ and efficiency $\rho \in (0, 1]$.

There are two primary strategies available to agents:

$$\mathcal{S} = \{\text{Scavenge } (S), \text{ Predate } (P)\}.$$

Scavenging aligns action with existing decay, avoiding direct conflict; predation creates or contests for fresh gradients via coercion. We write $x \in [0, 1]$ for the population share of S , so $1 - x$ play P .

Let $\kappa > 0$ denote expected conflict cost when two P -aligned agents (or a P against a defended resource) interact; $\alpha \in (0, 1]$ captures *conflict avoidance efficiency* of scavengers; $\beta \geq 0$ captures *depletion externality* of predation on the commons. The commons controller imposes an *entropy budget* in the form of a tax–subsidy pair $(\lambda, \mu) \geq 0$ that is applied to *net* entropy flux contributions: λ penalizes flux *into* the commons, μ rewards flux *out* (repair).

Affordance supply. Local, usable gradient available to agents is

$$G(x) = g + \rho \min\{K, \text{repair}(x)\} - \beta(1 - x), \quad (51)$$

where $\text{repair}(x)$ is an increasing function of x (scavengers contribute to repair through cooperative recycling). A simple linearization is

$$\text{repair}(x) = r_0 + r_1 x, \quad r_0, r_1 \geq 0. \quad (52)$$

D.2 Payoffs with Entropy Budgets

Each agent converts access to $G(x)$ into value according to their mechanism:

$$\pi_S(x) = \alpha G(x) - c_S + \mu \Delta J_S^{\text{out}}(x) - \lambda \Delta J_S^{\text{in}}(x), \quad (53)$$

$$\pi_P(x) = G(x) - c_P - \kappa(1-x) - \lambda \Delta J_P^{\text{in}}(x) + \mu \Delta J_P^{\text{out}}(x). \quad (54)$$

Here $\Delta J^{\text{in/out}}$ denote the agents marginal flux into/out of the commons. Assume

$$\Delta J_S^{\text{out}}(x) \geq 0, \quad \Delta J_S^{\text{in}}(x) \approx 0, \quad \text{and} \quad \Delta J_P^{\text{in}}(x) \geq 0, \quad \Delta J_P^{\text{out}}(x) \approx 0.$$

D.3 Replicator Dynamics and Stationary Conditions

Let $\bar{\pi}(x) = x \pi_S(x) + (1-x) \pi_P(x)$ be the mean payoff. Population dynamics follow a replicator equation:

$$\dot{x} = x(1-x) (\pi_S(x) - \pi_P(x)). \quad (55)$$

Stationary points occur at $x \in \{0, 1\}$ or at interior points where $\pi_S(x^*) = \pi_P(x^*)$.

Subtracting (54) from (53) and using (51)(52) gives

$$\begin{aligned} \pi_S(x) - \pi_P(x) = (\alpha - 1) \left[g + \rho \min\{K, r_0 + r_1 x\} - \beta(1-x) \right] + (c_P - c_S) + \kappa(1-x) \\ + \mu \Delta J_S^{\text{out}}(x) - \lambda \Delta J_P^{\text{in}}(x). \end{aligned} \quad (56)$$

Conflict-avoidant interior equilibrium. An interior fixed point $x^* \in (0, 1)$ exists if the right-hand side of (56) crosses zero within $(0, 1)$. Sufficient conditions (linear case where $r_0 + r_1 x \leq K$):

$$\exists x^* \in (0, 1) \text{ s.t. } (\alpha - 1) [g + \rho(r_0 + r_1 x^*) - \beta(1 - x^*)] + (c_P - c_S) + \kappa(1 - x^*) + \mu \Delta J_S^{\text{out}}(x^*) - \lambda \Delta J_P^{\text{in}}(x^*) = 0. \quad (57)$$

D.4 A Stability Theorem for Conflict Avoidance

Theorem .1 (Conflict-Avoidant Stability). *Suppose the linear regime $r_0 + r_1 x \leq K$ holds on $[0, 1]$, and there exist constants $\underline{J}_S > 0$, $\bar{J}_P > 0$ such that $\Delta J_S^{\text{out}}(x) \geq \underline{J}_S$ and $\Delta J_P^{\text{in}}(x) \leq \bar{J}_P$ for all x . If the entropy budget condition*

$$\mu \underline{J}_S + (c_P - c_S) + \kappa > (1 - \alpha) \left[g + \rho(r_0 + r_1) \right] + \lambda \bar{J}_P + (1 - \alpha) \beta \quad (58)$$

holds, then there exists a unique asymptotically stable fixed point $x^ \in (0, 1]$ with x^* increasing in μ , κ , ρ , and decreasing in β , λ , g . Moreover, if (58) holds with strict margin and α is close to*

1, then x^* lies near 1 (predator measure vanishes), and the expected conflict incidence is driven to zero.

Sketch. Under the linear regime, $\pi_S - \pi_P$ is affine in x . Condition (58) ensures $(\pi_S - \pi_P)(0) > 0$ and $(\pi_S - \pi_P)(1) \geq 0$, with strict positivity near at least one boundary. Affine monotonicity then implies a unique zero (or none) in $(0, 1)$; the replicator equation (55) yields local stability where $\partial_x(\pi_S - \pi_P) < 0$. Comparative statics follow from the signs in (56). The final clause follows by continuity as $\alpha \uparrow 1$. \square

Interpretation. Inequality (58) states that a combination of (i) *rewarding repair* ($\mu \underline{J}_S$), (ii) *higher predation overhead* ($c_P - c_S$), (iii) *cost of conflict* (κ), and (iv) *efficient commons* (ρ) must outweigh the apparent advantage of aggressive extraction arising from raw gradient g and depletion externalities β , net of any penalty λ levied on predations burden.

D.5 Potential Formulation and Social Objective

Define a *thermodynamic social potential*

$$\mathcal{V}(x) = -\bar{\pi}(x) + \frac{\gamma}{2} \left(\sum_i \nabla \cdot \mathcal{J}_{S_i} \right)^2 + \frac{\delta}{2} \max\{0, r_0 + r_1 x - K\}^2, \quad (59)$$

with $\gamma, \delta > 0$. The first term seeks to maximize average payoff; the second penalizes net entropy injection into the commons; the third penalizes capacity overflow. A system is *entropy-respecting* if x is chosen to minimize \mathcal{V} .

Proposition .2 (Entropy-Respecting Nash Alignment). *If agents follow myopic gradient ascent on π , while a commons controller adjusts (λ, μ) to minimize \mathcal{V} , then any stationary point that satisfies KKT conditions for (59) coincides with an interior replicator fixed point x^* and enforces $\sum_i \nabla \cdot \mathcal{J}_{S_i} = 0$ and $r_0 + r_1 x^* \leq K$.*

Idea. Treat (λ, μ) as Lagrange multipliers for the constraints on net flux and capacity. Stationarity of \mathcal{V} induces transfers that equate private and social gradients at equilibrium; replicator stationarity pins x^* . The flux and capacity constraints bind only when violated, by complementary slackness. \square

D.6 Microfoundations via RSVP Fluxes

Let u_S, u_P be the control fields for strategies S, P . Denote their induced entropy fluxes by $\mathcal{J}_S(u_S), \mathcal{J}_P(u_P)$. Conflict manifests as a dissipation spike $\mathcal{D} = \chi \|\mathbf{v}_P - \mathbf{v}_{\text{opp}}\|^2$ with coefficient $\chi > 0$. Then expected payoffs admit the field-theoretic forms

$$\pi_S = \int_{\Omega} (\alpha \langle \nabla S, \mathbf{v}_S \rangle - c_S) d\Omega + \mu \int_{\Omega} \nabla \cdot \mathcal{J}_S(u_S) d\Omega - \lambda \int_{\Omega} \nabla \cdot \mathcal{J}_S^{\text{burden}} d\Omega, \quad (60)$$

$$\pi_P = \int_{\Omega} (\langle \nabla S, \mathbf{v}_P \rangle - c_P - \kappa \mathbb{E}[\mathcal{D}]) d\Omega - \lambda \int_{\Omega} \nabla \cdot \mathcal{J}_P(u_P) d\Omega, \quad (61)$$

recovering (53)(54) under spatial homogenization. Conflict avoidance corresponds to the choice of u_S that minimizes $\mathbb{E}[\mathcal{D}]$ subject to target extraction.

D.7 Design Lemma for Commons Controllers

Lemma .3 (Budget Tuning for Zero-Conflict Regime). *Assume $\alpha \approx 1$ and the linear regime. If μ and λ are tuned such that $\mu \underline{J}_S - \lambda \bar{J}_P \geq \theta$ for some $\theta > (1 - \alpha)[g + \rho(r_0 + r_1)] + (1 - \alpha)\beta - (c_P - c_S) - \kappa$, then $x^* = 1$ is globally asymptotically stable for (55).*

Proof. Under the stated inequality, $\pi_S(x) - \pi_P(x) > 0$ for all $x \in [0, 1]$, so $\dot{x} > 0$ on $(0, 1)$ and $x(t) \rightarrow 1$. \square

D.8 Discussion

The analysis formalizes three claims: (i) *Scavenging* is a conflict-avoidant alignment to existing entropy gradients and can be socially optimal when commons repair is rewarded and predations externalities are priced. (ii) A *healthy commons* (ρ large, K adequate) converts scavenging from parasitic to regenerative by remitting repaired structure back into the affordance supply $G(x)$. (iii) *Conflict avoidance* emerges not from moral exhortation but from the equilibrium induced by entropy budgets (λ, μ) , capacity K , and the intrinsic costs $(c_P - c_S, \kappa)$.

In short, a civilization that tunes (λ, μ, K, ρ) to satisfy (58) implements the ancestral scavenger ethic at scale: it metabolizes decay, stabilizes the commons, and avoids war.

Appendix E: Commentary and Integration

E.1 Continuity from Ethology to Thermodynamics

Appendices C and D together trace an arc from ethology to formal physics. The scavenger model, first introduced as a cognitiveecological adaptation to entropy gradients, has here matured into a full-fledged entropic game theory. What began as a behavioural heuristic *affordance foraging* now finds quantitative expression in replicator dynamics and entropy budgets. This progression mirrors the general trajectory of the RSVP programme: beginning with phenomenology and evolution, proceeding through field dynamics, and culminating in formal governance models that preserve system-wide coherence.

The scavengers ancestral task was not domination but equilibration: to metabolize decay without entering direct conflict. This ancestral ethic, rediscovered through formalization, reveals the deep thermodynamic continuity between cognition, economy, and ecology. The same gradients that guided early hominins toward carrion now guide modern institutions toward distressed assets or informational debris. Whether in flesh, data, or finance, the vulture function persists an algorithm for detecting, absorbing, and redistributing entropy.

E.2 The Commons as Recursive Plenum

The introduction of a *commons buffer* in Appendix D operationalizes the philosophical principle first developed in Section 6: the commons is not a passive resource pool but an *entropic mediator*. It absorbs disorder and remits restored capacity, functioning as a thermodynamic analogue of the RSVP plenum itself.

In the Semantic Infrastructure framework, each agent or institution is a local module within a symmetric monoidal category of interaction. The commons is then the colimit of all such modules a dynamic equilibrium space that enforces entropy conservation through morphic closure. The merge operator $\mathcal{M}_{\text{commons}}$ defined in Section 6 and the entropy budget (λ, μ) of Appendix D are dual representations of the same constraint: *no agent may offload entropy without compensating repair elsewhere.*

E.3 Conflict Avoidance as Morphic Symmetry

The conflict-avoidant equilibrium characterized by Theorem D.4 corresponds, in the RSVP field equations, to a symmetry in the vector field \mathbf{v} such that

$$\nabla \cdot \mathbf{v} = 0 \quad \text{and} \quad \mathbf{v} \parallel \nabla S.$$

Here, agents move *with* the entropic flow rather than against it. This is the dynamical meaning of peace: velocity aligned with entropy gradient yields minimal dissipation. War arises when agents attempt to invert this alignment forcing \mathbf{v} against ∇S , creating shock fronts of destruction.

In Semantic Infrastructure, this symmetry is maintained via *co-cartesian merge* operations that combine informational trajectories without contradiction. The mathematical stability of the scavenger equilibrium thus generalizes to the categorical stability of distributed inference: conflict avoidance is the natural state of systems that preserve morphic compatibility under entropy constraints.

E.4 Relevance Activation and the Governance of Attention

From a cognitive standpoint, the same dynamics govern perception. *Relevance Activation Theory* identifies awareness as a limited resource allocated along entropy gradients: attention flows toward novelty, decay, and uncertainty. The scavenger mode of cognition therefore underlies not only material foraging but epistemic behaviour how minds and institutions decide *what matters*.

When aggregated, these flows of attention constitute the social vector field $\mathbf{v}_{\text{collective}}$. Without a regulating commons, such flows amplify conflict by overshooting regions of decay, competing for the same affordances, and exhausting informational ecosystems. The entropy budget (λ, μ) functions here as a *meta-attentional regulator*: a policy layer ensuring that collective focus repairs rather than depletes the shared epistemic environment.

E.5 Ethical and Civilizational Implications

The synthesis achieved across Appendices CD yields a unified ethical geometry:

- **Biological Level:** Conflict avoidance through opportunistic cooperation.
- **Economic Level:** Stability through entropy budgets that reward repair.
- **Cognitive Level:** Relevance activation aligned with commons renewal.
- **Ontological Level:** Entropy-respecting morphisms within the plenum.

E.6 Toward Entropic Constitutional Design

The formal results of Appendix D suggest explicit design parameters for sustainable governance:

1. Set μ/λ such that repair outflows exceed depletion inflows at equilibrium (§D.7).
2. Maintain commons efficiency ρ near unity through open data, transparency, and trust.
3. Ensure conflict costs κ are internalized by those who initiate antagonism.
4. Bound raw affordance gradients g via ecological, informational, and financial regulation to prevent runaway extraction.

These prescriptions constitute an *entropic constitution*: a set of dynamic laws ensuring that individual optimization aligns with collective regeneration. In the long arc of RSVP cosmology, such design represents the transition from a vulture phase (extractive cognition) to a plenum phase (integrative cognition).

E.7 Conclusion

The “Entropic Game Theory” of Appendix D therefore serves not merely as an economic model but as a canonical expression of the RSVP worldview: *all conflict is misaligned entropy flow*. By embedding the ancestral scavenger ethic into the mathematics of fields and games, we obtain a unified science of cooperation: a physics of peace grounded in the same thermodynamic laws that govern stars, minds, and markets.

Appendix F: Temporal and Multi-Scale Dynamics of the Epistemic Plenum

F.1 Motivation: Time as the Missing Dimension of Repair

The preceding appendices describe an equilibrium view of epistemic dynamics, where attention distributions x_i and gaps g_i adjust until the entropy budget balances. Yet in living knowledge systems, no equilibrium is permanent. Every successful repair alters the topology of opportunity: solved problems reveal deeper absences, and closure in one region induces stress in another. Time therefore enters the epistemic plenum not as an external parameter but as a *rate of transformation of ignorance*. The gap vector $g(t)$ is both the map of what remains to be known and the source of novelty that drives inquiry forward.

F.2 Dynamic Law of the Gap Operator

Let $y_i(t)$ denote the validated knowledge density in niche i . The gap $g_i(t) = |Ly(t)|_i$ from Appendix E measures relational discontinuity: high when local knowledge is under-connected or conceptually isolated. As knowledge accumulates, gaps close, but new ones

appear through conceptual differentiation. We therefore model g_i as a self-renewing, decaying field obeying

$$\dot{g}_i = -\delta_i g_i + \sigma_i (1 - g_i/K_g) \sum_{j=1}^N B_{ij} x_j + \zeta_i(t), \quad (62)$$

where $\delta_i > 0$ is the rate at which research closes existing questions, K_g is the saturation threshold beyond which novelty production slows, $B_{ij} \geq 0$ encodes spillovers from other niches (new discoveries in j expose latent problems in i), and $\zeta_i(t)$ captures exogenous perturbations (technological leaps, crises, paradigm shifts).

The nonlinear logistic term $(1 - g_i/K_g)$ ensures that the creation of new gaps is self-limiting: once a region becomes too conceptually fragmented, further innovation loses direction. Equilibrium occurs when $\dot{g}_i = 0$, giving

$$g_i^* = \frac{K_g \sigma_i \sum_j B_{ij} x_j + K_g \zeta_i / \sigma_i}{\delta_i K_g + \sigma_i \sum_j B_{ij} x_j + \zeta_i}. \quad (63)$$

Increased research activity (x_j) both repairs and reveals gaps, producing oscillatory cycles of discovery and consolidation akin to Kuhnian paradigms.

F.3 Temporal Coupling with Attention Dynamics

Combining (62) with the replicator–mutator flow (??) from Appendix E yields a two-field dynamical system:

$$\dot{x}_i = x_i(\pi_i(x, g) - \bar{\pi}(x, g)) + \sum_j x_j M_{ji} - x_i \sum_k M_{ik}, \quad (64)$$

$$\dot{g}_i = -\delta_i g_i + \sigma_i (1 - g_i/K_g) \sum_j B_{ij} x_j + \zeta_i. \quad (65)$$

Because π_i depends on g_i through the affordance gradient G_i , the system exhibits *delay-coupled feedback*: attention flows into high-gap regions, closing them over time and thereby displacing attention elsewhere. The resulting trajectory $(x(t), g(t))$ forms a dynamic attractor–repeller network that models the historical pulse of science—the rise and fall of paradigms, research fads, and integrative syntheses. Under modest assumptions (bounded ζ_i , small σ_i), the system converges to a quasi-periodic orbit where $\langle \dot{g}_i \rangle_t \approx 0$ and $\langle H(x) \rangle_t$ remains above H_{\min} .

F.4 Multi-Scale Commons Architecture

Knowledge is not governed by a single commons but by a nested hierarchy of interdependent buffers. Let $\mathcal{J} = \{1, \dots, J\}$ index domains (e.g. physics, biology, philosophy), each with local capacity K_j and efficiency ρ_j . Subfields $i \in \Omega_j$ share the same local buffer. Within

each domain, the entropy balance reads

$$\sum_{i \in \Omega_j} (J_i^{\text{in}} - J_i^{\text{out}}) = \dot{E}_j, \quad (66)$$

where \dot{E}_j is the rate of entropy transfer to or from higher scales (interdisciplinary coordination, global funding, cultural memory).

The global buffer enforces

$$\sum_{j=1}^J \rho_j \dot{E}_j = 0, \quad (67)$$

so that losses in one domain must be offset by regenerative activity elsewhere. This structure mirrors biological metabolism: each organ (discipline) consumes and restores differently, but total systemic entropy remains bounded.

Policy dynamics across scales. Each domain maintains its own entropy budget (λ_j, μ_j) , but a federated controller tunes a global pair (Λ, M) that modulates them:

$$\lambda_j = \Lambda + \eta_\lambda (\dot{E}_j / K_j), \quad \mu_j = M - \eta_\mu (\dot{E}_j / K_j),$$

with feedback coefficients $(\eta_\lambda, \eta_\mu) > 0$. Domains that export repaired structure ($\dot{E}_j < 0$) receive subsidies (higher μ_j); those that import excess entropy face taxes (higher λ_j). This implements a *fiscal federalism of knowledge*: local autonomy under global thermodynamic discipline.

F.5 Temporal Hierarchy and Resonant Governance

Because each subdomain evolves at its own intrinsic time scale $\tau_j \approx 1/\delta_i$, the coupled system (64)–(65)–(66) constitutes a hierarchy of oscillators. When properly tuned, these oscillators exhibit *resonant governance*: phase relationships among domains synchronize diversity cycles without destructive interference. Too tight a coupling (over-centralization) forces global phase locking and suppresses innovation; too loose a coupling (fragmentation) yields decoherence and loss of common purpose. Stability requires moderate coherence:

$$0 < \text{Cov}(\dot{g}_i, \dot{g}_j) < \epsilon \quad \forall i, j,$$

ensuring coordination without uniformity.

F.6 Empirical and Computational Prospects

The dynamic equations above lend themselves to simulation. Given empirical data on citation networks or concept graphs, one can estimate L , compute $g_i(t)$, and calibrate parameters $(\delta_i, \sigma_i, B_{ij}, \rho_j, K_j)$ to reproduce observed innovation cycles. Temporal cross-correlation of \dot{g}_i and \dot{x}_i provides a measurable signature of repair efficiency: periods where

attention lags gap signals indicate bureaucratic inertia, while excessive volatility indicates faddish overreaction. An ideal epistemic commons minimizes both lag and volatility a state of *critical responsiveness*.

F.7 Conceptual Integration

This temporal and multi-scale extension closes the loop of the RSVP epistemology. Just as the physical plenum maintains structure through continuous exchange between scalar capacity (Φ), vector flow (\mathbf{v}), and entropy (S), so the knowledge plenum maintains coherence through interaction of density (y), attention (x), and gap (g). At every level from neurons to networks to nations the same principle applies: *repair is never final; equilibrium is the maintenance of disequilibrium*. The temporal law of the gap and the hierarchical commons together form the skeleton of a thermodynamics of knowledge ecosystems, in which curiosity, cooperation, and memory are conserved energies within the evolving plenum of meaning.

Appendix G: Empirical and Simulation Design

G.1 From Philosophy to Experiment

The previous appendices have described an entropic epistemology: a system in which curiosity, attention, and ignorance form a coupled thermodynamic loop. The present section outlines how this model can be grounded empirically and explored through simulation. Its purpose is not to reduce thought to data, but to render the metabolism of knowledge measurable, comparable, and improvable. The empirical program that follows transforms the “thermodynamics of scientific revolutions” into an applied science of epistemic design.

G.2 Data Sources and Representational Infrastructure

The empirical substrate of this framework is the evolving network of published research, citations, and conceptual linkages. Each document, dataset, or experimental protocol becomes a node in a multi-layer graph $\mathcal{G}(t)$ whose edges encode semantic, methodological, and social relations. Time-resolved data from bibliometric repositories (Crossref, Semantic Scholar, OpenAlex), preprint archives (arXiv, bioRxiv), and collaborative metadata (GitHub, institutional repositories) serve as proxies for the evolving state variables:

$$\begin{aligned} y_i(t) &= \text{validated knowledge density in niche } i, \\ x_i(t) &= \text{fraction of active attention (authors, grants, citations)}, \\ g_i(t) &= \text{gap magnitude derived from graph Laplacian } L(t). \end{aligned}$$

Together, these yield the empirical instantiation of the RSVP epistemic plenum.

Constructing the Conceptual Graph. Nodes are clustered by topic modeling or citation community detection (e.g. spectral modularity, Leiden algorithm). Edge weights are computed from semantic embeddings or co-citation frequencies. The normalized Laplacian $L(t)$ is updated periodically to reflect the current conceptual topology. Gaps $g_i(t) = |L(t)y(t)|_i$ quantify discontinuity—the informational “voids” that attract attention.

G.3 Parameter Estimation and Calibration Strategies

Each parameter in the coupled system

$$\begin{cases} \dot{x}_i = x_i(\pi_i(x, g) - \bar{\pi}(x, g)) + \sum_j x_j M_{ji} - x_i \sum_k M_{ik}, \\ \dot{g}_i = -\delta_i g_i + \sigma_i(1 - g_i/K_g) \sum_j B_{ij} x_j + \zeta_i \end{cases}$$

has an empirical analogue.

1. Decay rate δ_i . Estimate by measuring the half-life of open questions: track how long highly-cited “problem statements” or open challenges persist before a significant solution cluster appears. Fit an exponential decay $g_i(t) \approx g_i(0)e^{-\delta_i t}$ within local epochs.

2. Innovation coefficient σ_i . Relate to the emergence rate of new concepts or methods within niche i : $\sigma_i \propto (\text{new unique keywords per year})/(\text{active authors})$. High σ_i indicates creative overproduction and rapid re-problematization.

3. Spillover matrix B_{ij} . Compute from the cross-citation or embedding influence matrix:

$$B_{ij} = \frac{\text{citations or semantic references from niche } j \text{ to } i}{\text{total citations from } j},$$

smoothed over time windows. It quantifies how activity in j reveals new opportunities in i .

4. Commons parameters (K_j, ρ_j) . Derive from resource and capacity indicators: grant funding, publication venues, reviewing bandwidth, and data repository throughput. ρ_j can be estimated from acceptance-to-submission ratios or time-to-publication metrics.

5. Attention mutation matrix M_{ij} . Infer from author topic-switching frequencies: how often researchers transition from one area to another between successive publications.

6. Exogenous shock ζ_i . Identify through sudden bursts of novelty (e.g. new instrumentation, crises, or major theoretical breakthroughs) that cannot be explained by endogenous dynamics.

Parameter inference proceeds via Bayesian filtering or variational inversion of the differential system, using observed time series $\{x_i(t), g_i(t)\}$ to estimate hidden coefficients.

G.4 Validation Metrics and Empirical Signatures

Testing the theory requires identifying empirical signatures that differentiate healthy, resonant epistemic ecosystems from pathological regimes.

1. Lag correlation. Compute the cross-correlation between \dot{g}_i and \dot{x}_i :

$$\tau_i^* = \arg \max_{\tau} \text{Corr}(\dot{g}_i(t), \dot{x}_i(t + \tau)).$$

Short, stable lags $\tau_i^* > 0$ indicate *critical responsiveness*. Large or oscillatory lags imply bureaucratic inertia (slow reaction) or faddishness (overshoot).

2. Entropy balance. Evaluate the entropy of attention $H(x) = -\sum_i x_i \log x_i$ and its rate of change \dot{H} . Healthy regimes maintain $\dot{H} \approx 0$ with $H \geq H_{\min}$; declining H signals monoculture and vulnerability to collapse.

3. Gap coverage. Monitor $\sum_i x_i g_i$ as an aggregate measure of epistemic efficiency: it should decline as repairs spread but oscillate within a bounded range, reflecting renewal.

4. Phase coherence across domains. Compute pairwise coherence Γ_{jk} between \dot{g}_i within domains Ω_j and Ω_k . Excessive $\Gamma_{jk} \approx 1$ indicates centralization (lockstep agendas); $\Gamma_{jk} \approx 0$ indicates fragmentation. Optimal regimes maintain moderate $0 < \Gamma_{jk} < \epsilon$.

5. Predictive power. Train the dynamical model on a historical window and test its ability to forecast emerging topics or declining ones. Successful prediction of attention shifts validates the entropic coupling hypothesis.

G.5 Simulation Environment

To explore counterfactual policies and governance regimes, the coupled equations are simulated on synthetic or empirical graphs.

Model architecture.

- State variables: (x_i, g_i) for each niche i , plus domain-level commons buffers (E_j) .
- Time discretization: Δt chosen to match publication cycles (e.g. one year).
- Integration: Euler or adaptive RungeKutta on (64)(65)(66).

Policy regimes. Three canonical regimes are compared:

Centralized budgeting: Single (Λ, M) for all domains. Simulates top-down science policy. Tends to reduce diversity and shorten τ_i^* (hyperreactivity).

Federated budgeting: Domain-specific (λ_j, μ_j) with soft coupling via (67). Produces multi-phase oscillations and higher $H(x)$.

Anarchic (unbudgeted) regime: $\lambda_j = \mu_j = 0$. Yields boombust cycles, redundancy, and runaway concentration.

Observables. Simulations track attention diversity, gap coverage, phase coherence, and global entropy flux. Visualizations plot trajectories in $(H, \sum x_i g_i)$ phase space to reveal attractor basins corresponding to stable epistemic equilibria.

G.6 Empirical Policy Testbed

The simulation environment doubles as a decision-support tool for research governance. By varying (λ, μ, K, ρ) , policymakers can experiment with alternative incentive schemes:

1. *Gap bounty:* increase μ_i in high- g_i niches to stimulate neglected research.
2. *Redundancy toll:* raise λ_i in congested clusters to discourage oversaturation.
3. *Diversity quota:* impose minimal entropy H_{\min} via funding allocation.
4. *Repair bonus:* reward publication of synthesis, replication, and data curation outputs that increase J_i^{out} .

These interventions can be evaluated through Monte Carlo ensembles to assess their effects on stability, diversity, and responsiveness.

G.7 Toward an Empirical Thermodynamics of Knowledge

The ultimate test of this theory lies in whether it can predict and modulate real epistemic phenomena: the birth of new disciplines, the decay of old ones, and the synchronization of discovery across domains. If validated, it would provide a new language for science policy: not a managerial metaphor but a literal thermodynamics of thought, where attention is energy, ignorance is potential, and governance is the shaping of entropy flow.

The methodology proposed here combining bibliometric reconstruction, differential modeling, and controlled simulation turns that vision into a research program. It converts the philosophy of Appendix F into a computational instrument: a feedback-controlled epistemic commons capable of steering humanity's collective intelligence toward critical responsiveness rather than collapse.

Appendix H: Political-Economic Instantiation of RSVP Dynamics

H.1 Vulture Capitalism as Field-Theoretic Pathology

Grace Blakeley's analysis in *Vulture Capitalism* documents the systematic consolidation of economic agency within state-corporate networks. In RSVP field theory, this corresponds

to a pathological field configuration where the vector potential \mathbf{A} (representing channels of agency and control) becomes concentrated in singular attractors, violating the entropy-respecting condition $\nabla \cdot \mathcal{J}_S \geq 0$.

The corporate-state nexus functions as a *negentropic sink*: it extracts capacity Φ from the broader plenum while suppressing the diversity of accessible microstates S . Formally, for a corporate entity C and state apparatus G :

$$\frac{\partial \Phi_{C \cup G}}{\partial t} = \alpha \Phi_{\text{plenum}} - \beta S_{\text{plenum}} + \gamma(t) \delta(\mathbf{r} - \mathbf{r}_0) \quad (68)$$

where $\gamma(t)$ represents bailout interventions that localize capacity, and the entropy deficit βS_{plenum} quantifies Blakeley's "death of freedom" — the systematic reduction of accessible life paths for most agents.

H.2 Corporate Planning as Degenerate Inference

Blakeley's crucial insight — that capitalism involves extensive planning, just undemocratically — finds precise expression in the CLIO (Closed-Loop Inference Optimization) framework. Corporate entities implement inference operators that minimize their *local* free energy while exporting entropy to their environment:

$$\mathcal{F}_{\text{corp}} = \mathbb{E}q(\mathbf{s})[\ln q(\mathbf{s}) - \ln p(\mathbf{s}|\mathbf{o})] + \lambda \nabla^2 S_{\text{environment}} \quad (69)$$

The Laplacian term $\nabla^2 S_{\text{environment}}$ represents the externalized cognitive and material costs of corporate optimization — what Blakeley identifies as systemic risk, environmental degradation, and democratic erosion.

This creates what we term *epistemic laminar flow*: a regime where corporate priors dominate the variational density $q(\mathbf{s})$, suppressing alternative futures and constraining the manifold of possible actions.

H.3 Bailouts as Lamphrodyne Interventions

The bailout mechanisms Blakeley documents function as *political lamphrodyne* — external control inputs that maintain corporate entities in metastable low-entropy states:

$$\mathcal{L}_{\text{bailout}} = \int \kappa(\mathbf{r}, t) \Phi_C(\mathbf{r}, t) d\mathbf{r} dt - \mu \oint \partial V \mathcal{J}_S \cdot d\mathbf{A} \quad (70)$$

The surface integral represents the entropy exported to taxpayers, workers, and future generations. This mathematical formulation captures Blakeley's central critique: what appears as market "correction" is actually entropy redistribution that preserves power asymmetries.

H.4 Democratic Planning as Colimit Operations

Blakeley's alternative democratic economic planning corresponds precisely to the category-theoretic structure of Semantic Infrastructure. Where corporate planning creates non-reciprocal morphisms, democratic planning instantiates proper colimits:

$$\text{DemPlan} = \underset{\substack{\text{communities} \\ \text{workers} \\ \text{ecological systems}}}{\text{colim}} \mathcal{M}_{\text{need}} \quad (71)$$

Each constituent defines its own semantic module \mathcal{M}_i with local utility function U_i , and the colimit operation $\mathcal{M}_{\text{need}}$ ensures no single module can dominate the universal property. This formalizes Blakeley's vision of distributed economic agency while satisfying the RSVP condition of entropy respectance: $\delta S/\delta t \geq 0$ across all modules.

H.5 Freedom as Entropic Capacity

Blakeley's critique of capitalist "freedom" finds its thermodynamic correlate in the relationship between entropy and accessible state space. What neoliberalism frames as freedom is actually:

$$\text{"Freedom"}_{\text{neoliberal}} = \prod_i \delta(\mathbf{v}i - \mathbf{v}_{\text{market}}) \quad (72)$$

a delta-function distribution in agency-space, while genuine freedom requires:

$$\text{Freedom}_{\text{genuine}} = \exp(S_{\text{config}}) = \exp\left(-\sum p_i \ln p_i\right) \quad (73)$$

where p_i represents the probability density over life paths. Blakeley's documented collapse of social mobility, wage stagnation, and precarity corresponds precisely to the narrowing of this configuration space.

H.6 Synthesis: From Critique to Formal Reconstruction

Blakeley's empirical analysis provides crucial validation of RSVP dynamics in socio-economic systems:

- Capital concentration manifests as $\nabla\Phi \rightarrow \infty$ at corporate loci
- Democratic erosion correlates with $S \rightarrow S_{\min}$
- Bailouts represent singular δ -function injections breaking field symmetry
- Alternatives require restoring $SO(n)$ symmetry in agency distribution

The task of democratic political economy thus becomes the design of entropy-respecting governance morphisms that maintain:

$$0 \leq \frac{\delta}{\delta t} \left(\frac{S_{\text{system}}}{S_{\text{max}}} \right) \leq \epsilon \quad (74)$$

preventing both corporate consolidation ($\rightarrow 0$) and chaotic disintegration ($\rightarrow \infty$).

This formalization bridges Blakeley's institutional critique with the mathematical infrastructure of RSVP cosmology, creating foundations for what might be termed *entropic political economy*—a rigorous science of freedom, power, and collective intelligence.

Appendix I: Empirical Indicators and Simulation Schema

I.1 Empirical Mapping of RSVPEconomic Quantities

To render the *entropic political economy* empirically testable, the following correspondence table maps RSVP field quantities to measurable macroeconomic indicators. Each mapping can be operationalized using publicly available economic, environmental, and institutional datasets.

RSVP Quantity	Interpretation	Empirical Proxy
Φ (Scalar Capacity)	Stored potential; productive capital or wealth	National capital stock
\mathbf{v} (Vector Agency)	Directional flow of agency and influence	Policy-lobby network
S (Entropy)	Diversity of accessible states; systemic freedom	Herfindahl-Hirschman Index
$\nabla \cdot \mathcal{J}_S$	Rate of entropic outflow (redistribution, repair)	Fiscal progressivity
$\gamma(t)\delta(\mathbf{r} - \mathbf{r}_0)$	Lamphrodynic bailout injection	Size and frequency of bailouts
λ, μ (Entropy budget coefficients)	Policy levers: depletion tax and repair subsidy	Wealth tax vs. green bond
ρ (Commons efficiency)	Capacity of institutions to recycle entropy	Administrative efficiency
\mathcal{M}_i (Semantic module)	Economic or social subsystem (sector, region)	Input-output table
$\text{colim}(\mathcal{M}_i)$	Democratic planning colimit	Participatory budgeting

These correspondences make the field variables measurable through existing economic data streams, enabling empirical calibration of the RSVP politiceconomic equations.

I.2 Dynamic Simulation Framework

The field equations of Appendix H can be discretized into a network simulation where each node represents an institution, firm, or policy subsystem. The dynamics follow the discretized plenum equations with feedback between scalar potential (Φ), entropy (S), and agency (\mathbf{v}).

Core update rules.

$$\Phi_i(t+1) = \Phi_i(t) + \Delta t \left[-\lambda_i \nabla \cdot \mathcal{J}_{S,i} + \gamma_i(t) - \eta (\Phi_i - \bar{\Phi}) \right], \quad (75)$$

$$S_i(t+1) = S_i(t) + \Delta t \left[\mu_i \nabla \cdot \mathcal{J}_{S,i} - \beta_i (\nabla \Phi_i)^2 + \xi_i(t) \right], \quad (76)$$

$$\mathbf{v}_i(t+1) = \mathbf{v}_i(t) + \Delta t \left[-\nabla \Phi_i + \chi \nabla S_i - \nu \mathbf{v}_i \right]. \quad (77)$$

- λ_i, μ_i act as local tax/subsidy controls governing depletion and repair.
- $\gamma_i(t)$ represents lamphrodynic bailout injections.
- $\xi_i(t)$ captures stochastic shocks (e.g. geopolitical events, technological change).
- η, χ, ν are damping coefficients representing redistribution inertia, adaptive learning rate, and frictional resistance.

The system is integrated forward using standard finite-difference or agent-based methods, with institutional entities exchanging entropy flux $\mathcal{J}_{S,ij}$ through network edges weighted by trade, credit, or policy coupling.

Governance regimes. Simulations compare alternative macro-regulatory architectures:

Free-market regime: $\lambda_i = \mu_i = 0$, $\gamma_i(t)$ endogenous.

Results in entropy collapse: few $\Phi_i \rightarrow \infty$, $S_{\text{system}} \rightarrow 0$.

Central-planned regime: Uniform (λ, μ) and global γ stabilization.

Produces oscillatory overshoot; excessive synchronization of Φ across nodes.

Entropic constitutional regime: Adaptive (λ_i, μ_i) enforcing Eq. (74).

Stabilizes diversity, maintains $\nabla \cdot \mathcal{J}_S \approx 0$, minimizes inequality and volatility.

I.3 Validation and Metrics

Empirical and simulation results can be compared via the following observables:

1. **EntropyInequality Coupling:** Test whether $S_{\text{macro}} = -\sum_i p_i \ln p_i$ is inversely correlated with capital concentration. Empirical benchmark: Gini index versus industrial diversity.
2. **Lamphrodynic Signature:** Identify bailout episodes as spikes in $\gamma(t)$ producing transient increases in Φ_C but no rise in S_{system} .
3. **Restorative Efficiency:** Measure $\dot{S}/\dot{\Phi}$ post-policy intervention as indicator of entropy-respecting repair.
4. **Phase-Coherence Index:** Cross-correlate $\Phi_i(t)$ across sectors; optimal governance yields intermediate coherence $0 < \Gamma < \epsilon$.
5. **Freedom Gradient:** Empirical entropy of mobility and occupational diversity as a function of Φ distribution, validating Eq. (73).

I.4 Conceptual Integration

The simulation schema operationalizes the central philosophical claim of the paper: that freedom, equality, and sustainability are not competing values but coupled thermodynamic invariants. An *entropic constitution* encoded in adaptive λ and μ policies preserves the condition

$$0 < \frac{dS_{\text{system}}}{dt} < \epsilon$$

by continuously redistributing surplus potential into new degrees of freedom. Economic justice thereby becomes a physical law of system stability.

Future empirical agenda.

- Calibrate the model on historical macroeconomic crises (2008, COVID-19) to extract $\gamma(t)$ profiles.
- Compare entropy balance across governance regimes (Nordic, East Asian, neoliberal).
- Extend network resolution to include ecological and cognitive subsystems for planetary-scale RSVP modeling.

I.5 Closing Perspective

Appendix I completes the transformation of the RSVP framework from metaphysical cosmology to empirical political economy. By identifying measurable proxies and computational procedures, it lays the groundwork for a *thermodynamics of freedom*: a discipline uniting physical conservation laws with moral and institutional design. The next horizon is experimental governance testing whether entropy-respecting constitutions can produce societies that are simultaneously freer, fairer, and more stable than any equilibrium yet achieved.

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ChapterReference Mapping

Chapter	Thematic Focus	Key References
1	Problem of fragmentation, unity through entropy and coordination	[Wiener(1948), Prigogine & Stengers(1984), Ashby(1956), Kauffman(1993)]
2	Field-theoretic substrate (Φ, \mathbf{v}, S) ; entropy as potential	[Landauer(1961), Jaynes(1957), Onsager(1931), Baez & Fong(2017), Rovelli(2021)]
3	Entropic Game Theory; commons stability	[Smith(1982), Hofbauer & Sigmund(1998), Friston(2010), Maynard Smith & Price(1973)]
4	Knowledge as coupled fields of attention and ignorance	[Kuhn(1962), Popper(1959), Arthur(1994), Holland(2012), Fortunato et al.(2018), Evans & Foster(2011)]
5	Vulture Capitalism; entropy collapse in capital flows	[Blakeley(2024), Minsky(1986), Keen(2011), Mirowski(2013), Wallerstein(2004)]
6	Evolutionary and cognitive roots of repair and opportunism	[Margulis(1998), Dawkins(1989), Gibson(1979), Calvin(1996), Dennett(2017)]
7	Governance and entropy budgets	[Ostrom(1990), Wiener(1950), Hayek(1945), Friston et al.(2022), Baez & Pollard(2022)]
8	Thermodynamics of freedom; synthesis	[Ortega y Gasset(1930), Whitehead(1929), Boulding(1966), Deutsch(2011)]