

# Irreversibility as Architecture: Physics, Computation, and the Limits of Transformation

Flyxion

February 12, 2026

## Abstract

This document articulates the shared conceptual structure underlying a diverse collection of projects spanning cosmology, mathematical physics, computation, artificial intelligence, epistemology, governance, and speculative design. Although these projects appear heterogeneous in domain and method, they are unified by a single organizing thesis: *structure is generated not by unconstrained possibility, but by irreversible constraint acting through entropy-limited transformations.*

The Relativistic Scalar–Vector Plenum (RSVP) theory provides the physical instantiation of this idea, modeling gravitation and cosmological structure as smoothing dynamics within a non-expanding thermodynamic medium. Mathematical extensions (derived-geometric formalization, AKSZ/BV quantization, recursive tiling models) investigate the admissible configuration spaces and transformation laws of such systems. Computational and semantic frameworks (TARTAN, SpherePop, EBSSC) reinterpret these dynamics as discrete rewriting, irreversible events, and entropy-bounded composition. Civic and AI projects explore how constraint-mediated stabilization may replace optimization-centric paradigms in governance and machine learning. Creative and pedagogical works translate these structures into narrative, symbolic, and educational forms.

Across all layers, the central object of study is not equilibrium but *metastability*: the maintenance of coherent form through controlled descent of entropy under constraint. The present essay establishes this common foundation before turning, in subsequent sections, to detailed expositions of each project.

# 1 Introduction: From Optimization to Constraint

Much of contemporary scientific and technological thought is organized around a paradigm of optimization. Systems are described as maximizing likelihoods, utilities, efficiencies, or predictive accuracies. This framework implicitly assumes that the generative driver of structure is the search for better states within a space of possibilities.

The research program described here begins from the opposite premise.

Systems do not primarily optimize. They *survive constraint*.

Physical structures, cognitive habits, institutions, and computational artifacts persist not because they locate optima, but because they discover trajectories that remain dynamically admissible under limited resources, irreversible histories, and entropy production.

The shift is subtle but foundational. Instead of asking

“What configuration is best?”

we ask

“What configurations can continue to exist without catastrophic dissipation?”

This reorientation replaces optimization landscapes with *viability manifolds* and replaces equilibrium analysis with *controlled relaxation*.

## 2 Entropy as a Generative Constraint

Entropy is typically interpreted as a measure of disorder. In this program it is treated instead as a *budget*: a quantity whose redistribution governs which transformations are dynamically accessible.

Let a system be described by state variables  $x \in \mathcal{X}$  and an entropy functional

$$S : \mathcal{X} \longrightarrow \mathbb{R}.$$

Rather than assuming the system maximizes or minimizes  $S$ , we consider flows

constrained by admissible entropy production rates:

$$\frac{dS}{dt} = \sigma(x, t),$$

where  $\sigma$  is neither strictly positive nor extremized, but bounded by structural constraints:

$$\sigma_{\min} \leq \sigma(x, t) \leq \sigma_{\max}.$$

These bounds encode physical, informational, or institutional limits. The system evolves not toward extremum but along trajectories that remain inside this admissible band.

Such flows generate *smoothing dynamics*: gradients are reduced, tensions redistributed, and metastable structures formed without invoking expansion, teleology, or global optimization.

### 3 Irreversibility as the Source of Identity

A second unifying idea is that identity is not primitive but accumulated through irreversible transitions.

Let  $\{\mathcal{E}_i\}$  denote a sequence of events. A system's state is not merely  $x(t)$  but the ordered history

$$H(t) = (\mathcal{E}_1, \mathcal{E}_2, \dots, \mathcal{E}_n).$$

We define an irreversible composition law

$$H_{n+1} = H_n \circ \mathcal{E}_{n+1},$$

where  $\circ$  is non-invertible:

$$H_n \neq H_{n+1}^{-1}.$$

This asymmetry gives rise to what may be called *historical mass*: accumulated constraint that shapes future admissible transitions.

In physics this appears as entropy production. In cognition it appears as habit. In governance it appears as institutional inertia. In computation it appears as stateful semantics.

Across domains, irreversibility is not noise but the mechanism by which systems

acquire structure.

## 4 Field-Theoretic Realization: The RSVP Ansatz

The RSVP framework provides a concrete physical instantiation of these principles. Instead of modeling spacetime as expanding, it introduces a plenum described by:

- a scalar entropy-density field  $\Phi(x, t)$ ,
- a baryonic flow vector  $\mathbf{v}(x, t)$ ,
- coupled evolution equations enforcing redistribution rather than metric growth.

A representative schematic system takes the form

$$\partial_t \Phi + \nabla \cdot (\Phi \mathbf{v}) = D \nabla^2 \Phi + \mathcal{R}(\Phi), \quad (1)$$

$$\partial_t \mathbf{v} + (\mathbf{v} \cdot \nabla) \mathbf{v} = -\nabla \Psi(\Phi) + \nu \nabla^2 \mathbf{v}. \quad (2)$$

Here:

- $\Psi(\Phi)$  encodes entropic potential rather than gravitational curvature,
- diffusion and transport terms represent smoothing,
- no scale factor  $a(t)$  appears.

Cosmic structure emerges as metastable attractors of redistribution dynamics rather than relics of an initial expansion event.

## 5 Generalization Across Domains

Once interpreted abstractly, the RSVP structure reappears in multiple domains as a pattern:

Physics	Entropy-driven smoothing fields
Computation	Rewrite systems under resource bounds
AI	Sparse inference constrained by representation cost
Governance	Institutions stabilizing under trust/entropy budgets
Cognition	Resolution allocation under attentional limits

The projects described later in this document explore these manifestations not as metaphors, but as structurally homologous systems.

The following sections (provided in subsequent messages) develop each project in detail, beginning with the physical and mathematical core before moving outward to computational, semantic, civic, and creative realizations.

## 6 The Relativistic Scalar–Vector Plenum

### 6.1 Motivation

Standard cosmological models introduce expansion as a primitive dynamical variable through the scale factor  $a(t)$ . In contrast, the RSVP framework asks whether the observational phenomena attributed to expansion may instead arise from internal redistribution processes within a non-expanding medium.

The guiding hypothesis is that cosmological evolution is governed not by metric dilation but by entropy-mediated smoothing in a relativistic continuum—a *plenum* whose structure evolves through constrained relaxation.

Thus, geometry is not taken as primary. Instead, the fundamental variables describe transport, redistribution, and dissipation.

### 6.2 Field Content

The minimal RSVP model is defined on a Lorentzian manifold  $(M, g_{\mu\nu})$  that is *not* assumed to evolve via a Friedmann scale factor. Instead, the dynamical degrees of freedom are:

- A scalar field  $\Phi(x)$  representing entropy density or configurational potential.
- A vector field  $v^\mu(x)$  representing directed baryonic or structural flow.
- A constitutive functional  $\Psi(\Phi)$  encoding resistance to compression or rarefaction.

The metric plays a kinematic role, providing causal structure, while dynamics are carried by  $(\Phi, v^\mu)$ .

### 6.3 Conservation Structure

Rather than Einstein's equations, RSVP begins from a generalized continuity principle:

$$\nabla_\mu J^\mu = \Sigma, \quad (3)$$

where  $J^\mu = \Phi v^\mu$  is an entropy-flux current and  $\Sigma$  is bounded production:

$$|\Sigma| \leq \Sigma_{\max}.$$

This expresses that entropy is redistributed locally and produced only within admissible limits. The universe is not driven toward equilibrium but toward metastable smoothing.

### 6.4 Dynamical Equations

A representative dynamical system may be written:

$$v^\nu \nabla_\nu v^\mu = -\nabla^\mu \Psi(\Phi) + \nu \square v^\mu, \quad (4)$$

$$\nabla_\mu (\Phi v^\mu) = D \square \Phi + \mathcal{R}(\Phi). \quad (5)$$

The first equation resembles Navier–Stokes transport on a relativistic background. The second governs entropy redistribution with diffusion constant  $D$  and nonlinear relaxation term  $\mathcal{R}$ .

No global expansion term appears.

### 6.5 Redshift Without Expansion

In this framework, observed cosmological redshift is interpreted as an energy-loss effect along null geodesics propagating through a medium undergoing gradual smoothing.

Let  $E$  denote photon energy. One postulates a transport law:

$$\frac{dE}{d\lambda} = -\alpha(\Phi)E, \quad (6)$$

where  $\lambda$  is affine parameter and  $\alpha(\Phi)$  depends on local entropy gradients.

Integration yields

$$1 + z = \exp \left( \int \alpha(\Phi) d\lambda \right), \quad (7)$$

producing a redshift relation without invoking  $a(t)$ .

## 6.6 Structure Formation as Metastability

Density contrasts emerge as localized failures of smoothing, stabilized by feedback between  $\Phi$  gradients and flow vorticity.

Let  $\delta\Phi$  denote perturbations. Linearization gives:

$$\partial_t \delta\Phi = D \nabla^2 \delta\Phi - \kappa \delta\Phi. \quad (8)$$

Modes with

$$k^2 < \kappa/D$$

decay slowly, producing long-lived structure analogous to galaxies.

These are not relic overdensities from an expanding plasma but dynamically sustained metastable features.

## 6.7 Thermodynamic Interpretation

The RSVP universe is not evolving *away from* a singular beginning but continually redistributing configurational tension.

Define a global functional

$$\mathcal{F}[\Phi] = \int_M \left( \frac{1}{2} |\nabla \Phi|^2 + U(\Phi) \right) dV. \quad (9)$$

Evolution approximately follows a constrained gradient descent:

$$\partial_t \Phi \sim - \frac{\delta \mathcal{F}}{\delta \Phi}$$

subject to transport coupling with  $v^\mu$ .

The cosmos behaves as a system perpetually relaxing without reaching uniformity.

## 6.8 Comparison With Standard Cosmology

Standard Model	RSVP
Expansion fundamental	Redistribution fundamental
Geometry drives matter	Matter-flow drives geometry interpretation
Singular origin required	No singular beginning required
Structure from inflation	Structure from smoothing failure

## 6.9 Interpretive Consequences

The RSVP proposal implies:

- Cosmology becomes a transport theory rather than a metric history.
- Time-asymmetry arises from irreversible redistribution, not boundary conditions.
- Gravitation is reinterpreted as directed entropy descent.

This establishes the physical core from which the remaining projects generalize.

The next section will develop the **Derived-Geometric Formalization**, which attempts to place these dynamics within a mathematically controlled configuration-space framework.

# 7 Derived-Geometric Formalization of RSVP

## 7.1 Why Derived Geometry?

The field equations of RSVP describe transport and relaxation dynamics, but they do not by themselves specify the full structure of the space of admissible configurations. Classical configuration spaces often fail when singularities, gauge redundancies, or non-transverse intersections appear. These failures are precisely the situations in which cosmological and thermodynamic models become mathematically ambiguous.

Derived geometry is introduced not as an embellishment but as a mechanism for retaining information that would otherwise be lost when configurations intersect non-generically.



Instead of treating the space of fields as a naive manifold

$$\mathcal{C} = \{(\Phi, v^\mu)\},$$

we regard it as a derived moduli problem encoding both configurations and their infinitesimal deformations.

## 7.2 Configuration Space as a Mapping Stack

Let  $M$  denote spacetime and  $\mathcal{T}$  a target space encoding admissible thermodynamic states. A field configuration is interpreted as a map

$$\varphi : M \longrightarrow \mathcal{T}.$$

The configuration space becomes the mapping stack

$$\mathcal{M} = \mathrm{Map}(M, \mathcal{T}),$$

enhanced to a *derived* object to retain obstruction and deformation data.

This shift allows singular configurations—for example, regions where entropy gradients vanish or flows intersect—to be treated as structured intersections rather than breakdowns.

## 7.3 Shifted Symplectic Structure

To describe dynamics,  $\mathcal{M}$  must carry a symplectic-like form. In derived geometry this appears as an  $n$ -shifted symplectic structure:

$$\omega \in \Gamma(\mathcal{M}, \Omega^2[n]),$$

satisfying a homotopical nondegeneracy condition.

Physically,  $\omega$  encodes the admissible redistribution of entropy and flow while accounting for redundancies analogous to gauge equivalence.

The shift reflects the fact that RSVP is not a Hamiltonian system in the classical sense; its symplecticity lives partly in cohomological degree.

## 7.4 Deformation Theory of Field Configurations

Given a configuration  $\varphi$ , small variations are governed by its cotangent complex

$$\mathbb{L}_\varphi,$$

which replaces the ordinary tangent space.

Obstructions to extending a deformation  $\delta\varphi$  lie in higher cohomology groups:

$$\text{Obs}(\varphi) \subset H^2(\mathbb{L}_\varphi).$$

These obstructions correspond physically to configurations that cannot relax smoothly, providing a rigorous language for metastability.

## 7.5 Entropy Functional as a Derived Action

The RSVP relaxation functional

$$\mathcal{F}[\Phi]$$

is lifted to a derived functional

$$\mathbb{F} : \mathcal{M} \rightarrow \mathbb{R},$$

whose critical locus is not a set but a derived space

$$\text{Crit}(\mathbb{F}).$$

This space contains both classical solutions and the infinitesimal directions in which relaxation can proceed.

## 7.6 Why This Matters Physically

Derived enhancement prevents us from discarding “failed” configurations that nonetheless influence nearby evolution. In a smoothing cosmology, such configurations represent stalled relaxation fronts, vortex pinning, or topological defects.

Rather than eliminating them, derived geometry tracks their influence as homological data.

## 7.7 Seed Models

Two prototype constructions guide the program:

1. Entropy scalar as a derived section problem:

$$\Phi \in \mathbf{R}\Gamma(M, \mathcal{E})$$

for a thermodynamic bundle  $\mathcal{E}$ .

2. Vector-flow moduli modulo symmetry:

$$\mathcal{V} = [\mathrm{Vect}(M)/\mathrm{Diff}(M)],$$

enhanced to encode degeneracies of transport.

These are not final formulations but controlled starting points.

## 7.8 Interpretation

Derived geometry supplies RSVP with a mathematically robust configuration space in which smoothing, obstruction, and metastability can be studied without collapsing into singularity pathologies.

The next section develops **RSVP Quantization**, where these structures are embedded into an AKSZ/BV framework to investigate deformation and fluctuation theory.

# 8 RSVP Quantization via the AKSZ/BV Formalism

## 8.1 Rationale for Quantization

If RSVP is to function as a genuine field theory rather than a phenomenological model, it must admit a fluctuation theory describing how configurations vary around metastable states. Traditional canonical quantization presumes a Hamiltonian structure, but RSVP dynamics are dissipative and constraint-driven rather than conservative.

The Batalin–Vilkovisky (BV) formalism is therefore adopted because it can treat systems with gauge redundancy, constraints, and nontrivial configuration spaces, especially when those spaces are derived or homological in nature.

## 8.2 AKSZ Construction

The Alexandrov–Kontsevich–Schwarz–Zaboronsky (AKSZ) method builds topological sigma models from a source graded manifold  $\Sigma$  and a target symplectic dg-manifold  $(\mathcal{T}, \omega, Q)$ .

For RSVP-inspired models we take:

$$\Sigma = T[1]M,$$

the shifted tangent bundle of spacetime, and choose a target whose coordinates encode entropy and transport variables.

A superfield takes the schematic form

$$\mathcal{X} = (\Phi, v^\mu, \text{ghosts}, \text{antifields}),$$

viewed as a map

$$\mathcal{X} : T[1]M \rightarrow \mathcal{T}.$$

## 8.3 BV Phase Space

The BV space of fields  $\mathcal{F}$  is equipped with an odd symplectic form

$$\Omega = \int_{T[1]M} \delta \mathcal{X}^A \wedge \delta \mathcal{X}_A^+,$$

where  $\mathcal{X}^+$  denotes antifields dual to  $\mathcal{X}$ .

This pairing encodes both dynamical variables and their admissible variations, including constraint directions corresponding to entropy-preserving transformations.

## 8.4 Classical Master Equation

The AKSZ action functional takes the general form

$$S = \int_{T[1]M} \langle \mathcal{X}^*, D\mathcal{X} + Q(\mathcal{X}) \rangle,$$

where  $D$  is the de Rham differential on  $T[1]M$  and  $Q$  is the target differential encoding relaxation dynamics.

Consistency requires the Classical Master Equation (CME):

$$\{S, S\} = 0.$$

Solving the CME ensures that the constraints defining entropy redistribution close algebraically and admit a well-defined deformation theory.

## 8.5 Interpretation of Ghost Structure

Ghost fields correspond not to gauge redundancies of geometry but to admissible redistributions of entropy that leave observable structure invariant. They encode equivalence classes of smoothing trajectories rather than coordinate symmetries.

Antifields represent sensitivity of configurations to irreversible perturbations.

## 8.6 Fluctuations Around Metastable States

Given a background configuration  $\mathcal{X}_0$ , perturbations are governed by the BV differential

$$s = \{S, \cdot\},$$

which generates cohomology classes describing physically distinct relaxation paths.

This replaces particle-like excitations with classes of admissible transformations.

## 8.7 Quantization Perspective

In this interpretation, “quantization” does not introduce discreteness but organizes the space of possible redistributions. Path integrals become sums over smoothing

histories:

$$Z = \int_{\mathcal{L}} e^{\frac{i}{\hbar} S},$$

where  $\mathcal{L}$  is a Lagrangian subspace in BV phase space.

## 8.8 Conceptual Outcome

The AKSZ/BV program reframes RSVP as a theory of structured fluctuations in entropy-driven media rather than as a particle theory. Quantization becomes a book-keeping device for transformation classes, not a claim about microscopic granularity.

The next section introduces the **TARTAN framework**, where these continuous ideas are realized through discrete recursive tilings and computational rewriting.

# 9 The TARTAN Framework: Discrete Realization of Entropic Smoothing

## 9.1 From Continuum Fields to Computational Grammars

While RSVP provides continuum equations, any attempt to simulate or operationalize the theory requires a discrete representation. The TARTAN framework (Trajectory-Aware Recursive Tiling with Annotated Noise) supplies this layer by interpreting field evolution as a sequence of local rewrite operations on structured tilings.

Instead of discretizing differential equations directly, TARTAN models evolution as transformations of configurations:

$$\mathcal{C}_{n+1} = \mathcal{R}(\mathcal{C}_n),$$

where  $\mathcal{R}$  is a constrained rewrite operator.

## 9.2 Tiling States

A configuration  $\mathcal{C}$  is represented as a labeled tiling:

$$\mathcal{C} = \{(T_i, \ell_i)\},$$

where each tile  $T_i$  carries labels  $\ell_i$  encoding entropy density, flow direction, and local constraints.

These tiles function as coarse-grained samples of the continuum fields:

$$\ell_i \approx (\Phi(x_i), v^\mu(x_i)).$$

### 9.3 Rewrite Dynamics

Evolution proceeds through admissible local rewrites:

$$(T_i, T_j) \longrightarrow (T'_i, T'_j)$$

subject to conservation-like constraints:

$$\sum \Phi_{\text{before}} \approx \sum \Phi_{\text{after}} + \epsilon,$$

with  $\epsilon$  bounded by entropy production limits.

This realizes smoothing as iterative redistribution rather than explicit integration of PDEs.

### 9.4 Gray-Code Trajectories

To minimize discontinuities, rewrite paths are chosen to differ minimally between steps. This is formalized through Gray-code adjacency:

$$d(\mathcal{C}_{n+1}, \mathcal{C}_n) = 1,$$

ensuring evolution proceeds through locally adjacent states.

Such trajectories approximate continuous flows while remaining combinatorially tractable.

### 9.5 Metric Structure

Configurations are compared using a transport metric inspired by Wasserstein distance:

$$W(\mathcal{C}_1, \mathcal{C}_2) = \inf_{\gamma} \int c(x, y) d\gamma,$$

where  $\gamma$  transports entropy labels between tilings.

This metric allows convergence analysis of discrete smoothing toward continuum relaxation.

## 9.6 Noise as Structured Perturbation

TARTAN introduces annotated noise fields  $\eta$  not as randomness but as bounded perturbations encoding unresolved microstructure:

$$\ell_i \mapsto \ell_i + \eta_i, \quad |\eta_i| \leq \delta.$$

Such perturbations model incomplete smoothing and generate metastable diversity.

## 9.7 Interpretive Role

TARTAN therefore functions as:

- a simulation grammar,
- a discretization strategy,
- a conceptual bridge between rewriting systems and thermodynamic flow.

The next section develops the **L-System Sigma Model bridge**, which attempts to formalize the continuum limit of such rewriting processes.

# 10 Derived L-System Sigma Models: From Rewriting to Field Evolution

## 10.1 Motivation

TARTAN provides a discrete operational model, but to justify it as more than a numerical heuristic we require a principled account of how rewrite systems approximate continuum dynamics. The L-system sigma-model program develops this bridge by



interpreting rewrite histories as trajectories in configuration space whose large-scale limit reproduces RSVP-style relaxation.

An L-system is defined by an alphabet  $\mathcal{A}$  and a production rule

$$\sigma : \mathcal{A} \rightarrow \mathcal{A}^*,$$

iteratively generating strings:

$$w_{n+1} = \sigma(w_n).$$

Here we reinterpret  $w_n$  not as symbolic strings but as combinatorial encodings of spatial configurations.

## 10.2 Configurations as Words

Associate each symbol  $a \in \mathcal{A}$  with a local field patch:

$$a \mapsto (\Phi_a, v_a^\mu).$$

A word

$$w = a_1 a_2 \cdots a_k$$

represents a stitched configuration obtained via a gluing functor:

$$\mathcal{G}(w) = \bigcup_i \mathcal{P}(a_i),$$

where  $\mathcal{P}(a_i)$  is the geometric patch corresponding to symbol  $a_i$ .

## 10.3 Rewrite Histories as Paths

Repeated application of  $\sigma$  produces a history:

$$w_0 \rightarrow w_1 \rightarrow \cdots \rightarrow w_n.$$

We interpret this as a path in configuration space:

$$\gamma : \mathbb{N} \rightarrow \mathcal{M}, \quad \gamma(n) = \mathcal{G}(w_n).$$

In the continuum limit, such paths approximate solutions of a variational flow.

## 10.4 Sigma-Model Interpretation

Define an action functional on rewrite histories:

$$S[\gamma] = \sum_n L(\gamma(n), \gamma(n+1)),$$

where  $L$  penalizes deviations from entropy-balanced redistribution.

Taking a scaling limit,

$$n \rightarrow t/\epsilon, \quad \epsilon \rightarrow 0,$$

one obtains a continuous functional:

$$S[\varphi] = \int_M \mathcal{L}(\Phi, \nabla \Phi, v, \nabla v) dV,$$

recovering a field-theoretic action analogous to RSVP.

## 10.5 Error Control

The discrepancy between discrete rewriting and continuum evolution is quantified by:

$$\|\Phi_{\text{rewrite}} - \Phi_{\text{continuum}}\| \leq C\epsilon.$$

Thus rewriting provides a controlled approximation rather than a metaphor.

## 10.6 Ethical Rewriting (Interpretive Layer)

The term “ethical” refers to admissibility constraints placed on rewrites:

$$\sigma \text{ allowed only if } \Delta S \leq S_{\max}.$$

This enforces bounded transformation cost, mirroring entropy budgets in physical and civic systems.

## 10.7 Outcome

The L-system sigma model demonstrates how generative rewriting, discrete tilings, and continuum relaxation can be mathematically aligned, forming the conceptual hinge between RSVP physics and computational implementations.

The next section turns to **SpherePop Calculus**, which abstracts these irreversible transformations into a general semantic framework.

# 11 SpherePop Calculus: A Semantics of Irreversible Events

## 11.1 From Dynamics to Event Structure

Where RSVP describes physical redistribution and TARTAN describes computational rewriting, SpherePop abstracts a deeper structural feature shared by both: systems evolve through *irreversible commitments*. Once a transformation occurs, it cannot be undone without introducing new history.

SpherePop therefore models systems not as trajectories in state space but as accumulations of irreversible events called *pops*.

## 11.2 Basic Objects

A SpherePop system consists of:

- A set of generators  $\mathcal{E}$  of elementary events,
- A partial order  $\preceq$  encoding causal admissibility,
- A history object  $H$  formed by compositional accumulation.

A history is written

$$H = e_1 \circ e_2 \circ \cdots \circ e_n,$$

where  $\circ$  is non-invertible:

$$e_i^{-1} \notin \mathcal{E}.$$

### 11.3 Irreversibility as Structure

Unlike group composition, SpherePop composition forms a category without inverses. The structure is closer to a filtered poset:

$$H_1 \preceq H_2 \quad \text{iff } H_2 \text{ extends } H_1.$$

Identity is therefore defined historically rather than instantaneously.

### 11.4 Geometric Interpretation

Histories embed into a geometric realization:

$$|H| \subset \mathbb{R}^N,$$

where each pop adds a new dimension representing constraint accumulation.

This produces a stratified configuration space rather than a smooth manifold.

### 11.5 Connection to RSVP

RSVP field evolution can be interpreted as a continuous limit of SpherePop accumulation:

$$\Phi(t + \Delta t) = \Phi(t) \oplus \delta H,$$

where  $\delta H$  is an infinitesimal pop corresponding to entropy redistribution.

Thus SpherePop provides a semantic layer describing what RSVP equations mean operationally.

### 11.6 Operadic Structure

Events compose according to an operad  $\mathcal{O}$ :

$$\mathcal{O}(n) : (e_1, \dots, e_n) \mapsto e,$$

capturing how multiple local transformations fuse into a single macroscopic change.

This reflects how many microscopic redistributions yield one observable structure.

## 11.7 Computational Interpretation

In programming terms, a SpherePop system behaves like an append-only log:

$$H_{n+1} = H_n \cup \{e_{n+1}\}.$$

State is reconstructed from history rather than stored independently.

## 11.8 Conceptual Role

SpherePop supplies a general semantics of irreversible transformation applicable to physics, computation, cognition, and governance.

The next section develops the **Entropy-Bounded Sparse Semantic Calculus (EBSSC)**, which introduces quantitative constraints governing how such histories may combine.

# 12 Entropy-Bounded Sparse Semantic Calculus (EBSSC)

## 12.1 Motivation

SpherePop provides a qualitative description of irreversible accumulation, but practical systems require quantitative criteria determining which compositions are admissible. EBSSC introduces an operator calculus governing how structures may combine under bounded informational cost.

The guiding principle is that semantic combination is not free. Each merge or inference must remain within an entropy budget.

## 12.2 Semantic Objects

Let  $\mathcal{S}$  denote a space of structured objects (texts, models, configurations). EBSSC equips  $\mathcal{S}$  with:

- A sparsity measure  $\sigma : \mathcal{S} \rightarrow \mathbb{R}_{\geq 0}$ ,

- An entropy functional  $E : \mathcal{S} \rightarrow \mathbb{R}_{\geq 0}$ ,
- A merge operator  $\mu : \mathcal{S} \times \mathcal{S} \rightarrow \mathcal{S}$ .

### 12.3 Entropy Budget Constraint

A merge is admissible only if

$$E(\mu(a, b)) \leq E(a) + E(b) + \Delta,$$

where  $\Delta$  is a bounded production allowance.

This mirrors RSVPs bounded entropy generation.

### 12.4 Sparsity Preservation

To avoid combinatorial explosion, EBSSC requires sparsity monotonicity:

$$\sigma(\mu(a, b)) \leq \sigma(a) + \sigma(b).$$

This ensures compositions remain interpretable and computationally tractable.

### 12.5 Operator Dynamics

Repeated merges generate a trajectory:

$$s_{n+1} = \mu(s_n, x_n),$$

analogous to rewrite evolution or entropy redistribution.

Stability emerges when entropy growth saturates:

$$\lim_{n \rightarrow \infty} \frac{E(s_n)}{n} = 0.$$

### 12.6 Lyapunov Interpretation

Define a functional

$$\mathcal{L}(s) = E(s) + \lambda \sigma(s).$$

Admissible transformations satisfy

$$\mathcal{L}(s_{n+1}) - \mathcal{L}(s_n) \leq C,$$

establishing bounded semantic drift.

## 12.7 Relation to Information Theory

While Shannon entropy may instantiate  $E$ , EBSSC treats entropy abstractly as any monotone cost functional compatible with composition.

Thus the calculus can apply equally to data fusion, model updating, or institutional decision processes.

## 12.8 Interpretive Role

EBSSC operationalizes the constraint-first worldview by specifying quantitative limits on how structures grow, ensuring that complexity arises through controlled accretion rather than unconstrained expansion.

The next section turns to the **Computational and Simulation Layer**, focusing on the RSVP Field Simulator and related numerical projects.

# 13 Computational Realization: The RSVP Field Simulator

## 13.1 Purpose

The RSVP Field Simulator is not merely a visualization tool but an experimental environment for testing whether entropy-driven smoothing can reproduce structure formation without metric expansion. It serves as a laboratory in which continuum theory, discrete realization, and semantic constraints can be compared.

## 13.2 Discretization Strategy

Fields are represented on a lattice or spectral grid:

$$\Phi(x, t) \rightarrow \Phi_i(t), \quad v^\mu(x, t) \rightarrow v_i^\mu(t).$$

Rather than naive finite differencing, the simulator employs transport-aware updates:

$$\Phi_i^{t+\Delta t} = \Phi_i^t - \Delta t \nabla \cdot (\Phi v)_i + D \Delta t \nabla^2 \Phi_i.$$

These updates approximate the redistribution law central to RSVP.

## 13.3 Spectral Implementation

To capture long-range smoothing, fields are often evolved in Fourier space:

$$\hat{\Phi}_k(t + \Delta t) = \hat{\Phi}_k(t) \exp(-Dk^2 \Delta t) + \hat{\mathcal{R}}_k.$$

This representation allows efficient modeling of cosmological-scale relaxation.

## 13.4 Coupled Flow Evolution

Velocity updates follow a constrained Navier–Stokes-like form:

$$v_i^{t+\Delta t} = v_i^t - \Delta t (\mathbf{v} \cdot \nabla) v_i - \Delta t \nabla \Psi(\Phi_i) + \nu \Delta t \nabla^2 v_i.$$

The coupling ensures that entropy gradients directly influence transport.

## 13.5 GPU-Oriented Kernels

Because smoothing dynamics require large spatial domains, implementations are designed for parallel execution:

$$\Phi^{t+\Delta t} = \mathcal{K}_{\text{GPU}}(\Phi^t, v^t).$$

Each kernel represents a localized redistribution step compatible with TARTAN



rewriting semantics.

## 13.6 Metastability Detection

To identify structure formation, the simulator tracks persistence measures such as

$$\chi(t) = \int |\nabla \Phi|^2 dV.$$

Plateaus in  $\chi(t)$  indicate stabilized configurations analogous to galaxies.

## 13.7 Toward Consciousness Metrics: $\phi_{\text{RSVP}}$

An exploratory extension defines coherence measures:

$$\phi_{\text{RSVP}} = \int \Phi(x) \kappa(x) dV,$$

where  $\kappa$  encodes coupling between flow and entropy gradients.

This is not yet fixed but represents attempts to quantify organized complexity.

## 13.8 Interpretive Role

The simulator connects theory with falsifiability. If smoothing dynamics cannot reproduce observed clustering, RSVP fails empirically; if they can, expansion is no longer required as an explanatory primitive.

The next section develops the **Governance and Socio-Technical Extensions**, where constraint-first dynamics are translated into institutional and civic systems.

# 14 Governance and Socio-Technical Dynamics

## 14.1 From Physical Constraints to Institutional Stability

If RSVP models physical structure as entropy-limited redistribution, governance systems may be interpreted analogously. Institutions do not optimize abstract utility;

they stabilize flows of trust, information, and resources under bounded capacity.

This motivates a translation of thermodynamic reasoning into civic design.

## 14.2 Recursive Futarchy

Recursive Futarchy proposes decision architectures where policies are evaluated not by predicted optimality but by their effect on system stability metrics.

Let  $X(t)$  represent institutional state variables. Evolution is governed by

$$\dot{X} = F(X, u),$$

with control inputs  $u$  chosen to maintain bounded entropy production:

$$E(X(t)) \leq E_{\max}.$$

Policy becomes a constraint-regulation problem rather than a maximization problem.

## 14.3 Entropy-Bounded Governance

Define a governance entropy functional

$$E_G = \alpha \text{ information loss} + \beta \text{ coordination cost} + \gamma \text{ trust dispersion}.$$

Admissible reforms must satisfy

$$\Delta E_G \leq \varepsilon,$$

ensuring institutional transitions remain metabolizable.

## 14.4 Lamphron–Lamphrodyne Cycles

These conceptual phases describe alternating regimes of stabilization and reintegration:

$$\text{Lamphron phase : } \nabla E_G \approx 0 \quad (\text{steady operation}), \quad (10)$$

$$\text{Lamphrodyne phase : } \partial_t E_G < 0 \quad (\text{structural smoothing}). \quad (11)$$

The cycles are heuristic descriptors of controlled restructuring rather than catastrophic reform.

## 14.5 Adaptive Trust Dynamics

Trust is treated as a conserved transport quantity:

$$\partial_t \tau + \nabla \cdot (\tau w) = D_\tau \nabla^2 \tau.$$

Breakdowns correspond to shock-like discontinuities; governance aims to avoid such gradients.

## 14.6 Operator Ecology and Entropy Ledgers

Institutions are modeled as networks of operators  $\mathcal{O}_i$  consuming entropy budgets. Accounting becomes:

$$\sum_i E_i \leq E_{\text{system}},$$

analogous to thermodynamic bookkeeping.

## 14.7 Interpretive Outcome

Governance appears as a distributed control system whose legitimacy derives from maintaining metastability rather than achieving ideal outcomes.

The next section examines **Artificial Intelligence and Machine Learning Extensions**, where similar principles reshape representation and alignment strategies.

# 15 Artificial Intelligence Under Entropy Constraints

## 15.1 Motivation

Contemporary machine learning emphasizes optimization of loss functions over large parameter spaces. This paradigm mirrors expansion cosmology: growth and scaling are assumed to generate structure automatically.

The entropy-bounded perspective instead asks how representations remain stable and interpretable under limited informational budgets.

## 15.2 Pixel-Stretching Algorithms

Pixel-stretching is an applied attempt to reveal latent structure before learning occurs. Given an image tensor  $I(x)$ , preprocessing applies logarithmic scaling:

$$I'(x) = \log(1 + \lambda I(x)),$$

amplifying low-intensity features.

Edge-sensitive transport is introduced via Sobel filtering:

$$G(x) = \|\nabla I'(x)\|,$$

creating a structural halo that guides downstream models.

## 15.3 Gaussian Velocity Auras

Local gradients are extended into contextual envelopes:

$$A(x) = \int G(y) \exp\left(-\frac{|x - y|^2}{2\sigma^2}\right) dy,$$

producing multi-scale coherence signals.

These operations aim to externalize relationships that neural networks would otherwise have to infer implicitly.

## 15.4 Entropy-Bounded AI

Training is interpreted as a constrained inference trajectory:

$$\theta_{t+1} = \theta_t - \eta \nabla L(\theta_t)$$

subject to representation entropy bounds:

$$E(\theta_{t+1}) \leq E(\theta_t) + \delta.$$

This reframes alignment as maintaining interpretable compression rather than maximizing reward proxies.

## 15.5 Constraint-First Alignment

Rather than specifying goals, systems are designed with admissibility envelopes:

$$\mathcal{A} = \{x \mid E(x) \leq E_{\max}\}.$$

Behavior emerges inside  $\mathcal{A}$ , analogous to physical viability regions.

## 15.6 Interpretive Role

AI becomes another instance of entropy-regulated transformation, where learning corresponds to controlled structural accretion.

The next section develops the **Philosophical and Cognitive Frameworks** that generalize these principles beyond formal systems.

# 16 Philosophical and Cognitive Foundations

## 16.1 Constraint-First Ontology

The philosophical foundation of the research program is the inversion of a long-standing metaphysical assumption. Classical metaphysics and modern optimization theory both privilege possibility: the world is treated as a space of options from which selections are made.

Constraint-first ontology asserts instead that what exists is determined primarily by what cannot happen. Structure arises as the residue of excluded transformations.

Formally, if  $\mathcal{X}$  denotes the space of conceivable states and  $\mathcal{C} \subset \mathcal{X}$  the admissible subset under constraints, then reality is governed by

$$x(t) \in \mathcal{C} \quad \text{for all } t,$$

with evolution defined by boundary maintenance rather than objective maximization.

## 16.2 Simulated Agency

Within this framework, agency is not an optimizing chooser but a resolution-modulating process. A cognitive system dynamically allocates descriptive resolution to maintain stability under limited resources.

Let  $R(t)$  denote representational resolution. Cognitive evolution satisfies

$$\frac{dR}{dt} = f(\text{prediction error, resource bounds}),$$

rather than utility gradients.

This yields behavior that appears deliberative without invoking separate reasoning modules.

## 16.3 Aspect Relegation Theory

Aspect Relegation Theory argues that automatic behavior is compressed deliberation rather than a distinct cognitive faculty.

A solved task transitions from explicit modeling  $M_{\text{exp}}$  to relegated form  $M_{\text{rel}}$  via

$$M_{\text{rel}} = \mathcal{C}(M_{\text{exp}}),$$

where  $\mathcal{C}$  is a constraint-driven compression operator preserving viability while reducing computational cost.

Thus cognition oscillates between expansion and relegation of descriptive detail.

## 16.4 Entropy Descent as Epistemology

Knowledge acquisition is modeled as smoothing across conceptual gradients. Let  $K(x)$  represent conceptual tension within a theory space. Learning follows

$$\partial_t K = -\nabla \cdot J_K + \Sigma_K,$$

mirroring RSVP redistribution equations.

Understanding therefore corresponds to reducing incompatible gradients rather than accumulating facts.

## 16.5 Never Bored: Voluntary Constraint

Creative productivity arises from self-imposed constraints that define manageable transformation domains. The deliberate restriction of possibility generates a navigable search region:

$$\mathcal{C}_{\text{chosen}} \subset \mathcal{X}.$$

Innovation is then an exploration of  $\mathcal{C}_{\text{chosen}}$  rather than an unbounded search.

## 16.6 Interpretive Role

These cognitive and philosophical strands articulate the same structural claim observed in physics and computation: persistence and intelligibility arise from bounded transformation, not maximal freedom.

The next section turns to **Creative and Narrative Projects**, where these ideas are explored through symbolic and dramatic forms rather than formal models.

# 17 Creative and Narrative Explorations

## 17.1 Narrative as Structural Experiment

The creative projects within this program are not ancillary illustrations but alternative laboratories in which constraint-mediated dynamics can be examined through symbolic systems rather than equations. Narrative provides a medium for testing how irreversible commitments generate identity, conflict, and stabilization in human-scale settings.

## 17.2 The Incoherence

*The Incoherence* is a screenplay-scale work dramatizing epistemic conflict between competing frameworks of explanation. Characters function as embodiments of incompatible constraint systems rather than psychological archetypes.

The dramatic structure follows an irreversible accumulation of interpretive commitments:

$$H_{n+1} = H_n \cup \{\text{interpretive act}\},$$

mirroring SpherePop history formation.

The narrative explores whether reconciliation can occur without erasing accumulated structure.

### **17.3 Flower Wars**

This project interprets ritualized conflict as a metastable regulatory mechanism. Violence is neither eliminated nor allowed to escalate unboundedly; it is constrained into repeatable, symbolically encoded encounters.

Such systems can be modeled as bounded dissipation processes:

$$\Delta E_{\text{social}} \leq E_{\text{max}},$$

maintaining cultural continuity while releasing structural tension.

### **17.4 Bounded Violence (Analytical Companion)**

The companion essays analyze these dynamics explicitly, treating ritual warfare as an engineered entropy-release mechanism analogous to controlled thermodynamic relaxation.

### **17.5 Deep Green Era**

This speculative world-building line imagines a technological civilization reorganized around long-term constraint management rather than growth. Ecological cycles replace expansion metrics as the organizing narrative principle.

### **17.6 Visions of a Spirit Seer**

A symbolic reinterpretation project drawing on historical visionary literature to explore perception as layered constraint filtering rather than passive reception.



## 17.7 Interpretive Role

Creative works allow qualitative investigation of ideas that remain abstract in mathematical treatment, demonstrating how constraint-first dynamics manifest in cultural and psychological domains.

The next section examines **Civic and Infrastructure Design Concepts**, where these ideas are translated into speculative engineering proposals.

# 18 Civic and Infrastructure Design Concepts

## 18.1 From Institutional Theory to Material Systems

Where the governance work models institutional dynamics abstractly, the civic design projects imagine how constraint-mediated stabilization might appear in physical infrastructure. These proposals are speculative but structured as design hypotheses rather than utopian blueprints.

## 18.2 Yarncrawler

The Yarncrawler concept envisions slow-moving maintenance systems that continuously repair infrastructure as they traverse it. Instead of periodic large-scale interventions, repair is distributed temporally and spatially.

Let  $I(x, t)$  denote infrastructure integrity. Yarncrawler dynamics aim to maintain:

$$\partial_t I = -\lambda D(x, t) + \rho R(x, t),$$

where  $D$  represents degradation and  $R$  incremental repair delivered through traversal.

The goal is metastable maintenance rather than restoration cycles.

### 18.3 Dynamic Garbage Rerouting

This proposal replaces static collection routes with responsive logistics informed by local signaling. Waste accumulation  $W(x, t)$  becomes a transport variable:

$$\partial_t W + \nabla \cdot (Wu) = S(x, t),$$

with routing velocity  $u$  adjusted in real time to smooth gradients.

The system behaves analogously to entropy redistribution.

### 18.4 Writable Urban Surfaces

Cities are reimagined as editable substrates whose physical and informational layers can be incrementally rewritten. Infrastructure becomes a medium for controlled transformation rather than static construction.

### 18.5 Xylomorphic City Architecture

Inspired by forest ecologies, this framework models urban systems as growth-constrained networks. Structural persistence emerges from local adaptation rules rather than centralized planning.

### 18.6 Mycelial Microchips

A speculative extension proposing distributed computation embedded within organic or semi-organic substrates, emphasizing redundancy, repairability, and gradual evolution.

### 18.7 Interpretive Role

These civic concepts attempt to translate entropy-aware design principles into tangible engineering metaphors, exploring how systems might be built to remain dynamically repairable.

The next section considers **Numeration, Symbolic Systems, and Pedagogy**, addressing how representation itself shapes constraint-mediated understanding.

## 19 Numeration, Symbolic Systems, and Pedagogy

### 19.1 Representation as Constraint Engineering

Mathematical notation and symbolic systems are often treated as neutral vehicles for expressing thought. In this program they are understood as active constraint mechanisms that shape which inferences are easy, which are difficult, and which remain invisible.

A representation system is therefore modeled as a transformation:

$$\mathcal{R} : \mathcal{X} \longrightarrow \mathcal{S},$$

mapping conceptual states into symbolic encodings whose structure influences subsequent reasoning.

### 19.2 Base-1.5 (Unidimary) Numeration Experiments

The exploration of nonstandard positional systems, such as base-1.5, investigates how arithmetic structure changes when conventional scaling assumptions are altered.

Given radix  $r \notin \mathbb{N}$ , expansions take the form:

$$x = \sum_k d_k r^k, \quad d_k \in \{0, 1\}.$$

These systems reveal that numerical representation is not unique but contingent, reinforcing the idea that mathematical stability arises from chosen constraints rather than intrinsic necessity.

### 19.3 Orthography and Script Tooling

Experiments with alternative alphabets, transliteration schemes, and symbolic overlays examine how encoding choices alter interpretability and compression of meaning.

Let  $L$  denote a language and  $\Sigma$  a script. Translation is treated as a structural morphism:

$$T : (L, \Sigma_1) \rightarrow (L, \Sigma_2),$$

with informational cost measured through entropy-like metrics.

## 19.4 Basic Introductions Program

This pedagogical initiative produces minimal-prerequisite expositions designed to reduce conceptual gradients without oversimplification.

Educational smoothing may be modeled analogously to RSVP diffusion:

$$\partial_t U = D \nabla^2 U,$$

where  $U$  represents learner uncertainty.

The aim is not maximal simplification but controlled redistribution of difficulty.

## 19.5 Interpretive Role

These projects emphasize that understanding is mediated by representational choices. By redesigning notation and pedagogy, one reshapes the admissible pathways through conceptual space.

The next section examines **Socio-Technical Critique and Alternative Platforms**, where constraint-first analysis is applied to contemporary digital systems.

# 20 Socio-Technical Critique and Alternative Platforms

## 20.1 Optimization Pathologies in Digital Systems

Modern digital platforms are overwhelmingly organized around engagement optimization. Metrics such as click-through rate, watch time, or behavioral prediction accuracy function as objective functions:

$$\max_{\theta} U(\theta),$$

where  $\theta$  denotes system parameters and  $U$  a proxy for attention capture.

Within the constraint-first perspective, this paradigm is structurally unstable because it removes the very limits that generate coherent behavior. When optimization is unconstrained by entropy-like costs, systems amplify noise, feedback loops, and adversarial dynamics.

## 20.2 Advertising Became AI’s Original Sin

This project advances the thesis that large-scale machine learning inherited its alignment pathologies from advertising-driven optimization. The training objective effectively became:

$$\theta^* = \arg \max_{\theta} \mathbb{E}[\text{engagement}],$$

subject to minimal structural constraint.

Such objectives produce runaway Goodhart effects:

$$\text{Metric} \uparrow \quad \text{while} \quad \text{meaning} \downarrow .$$

The critique reframes this as an entropy mismanagement problem: platforms maximize signal extraction while externalizing disorder.

## 20.3 Engagement-Optimized Architecture Critique

Digital ecosystems can be modeled as dynamical systems whose informational entropy  $E_I$  grows without regulatory bounds:

$$\partial_t E_I \gg 0.$$

Unbounded amplification leads to polarization, fragmentation, and epistemic instability. The analysis treats these not as sociological accidents but as predictable consequences of unconstrained objective maximization.

## 20.4 Gallery-First, Merge-Aware Publication Systems

As an alternative, the program proposes knowledge infrastructures that privilege compositional integrity over attention capture. Instead of ranking outputs by engagement, artifacts are arranged within merge-compatible structures:

$$\mathcal{K}_{n+1} = \mu(\mathcal{K}_n, \Delta),$$

with  $\mu$  constrained by EBSSC-style entropy budgets.

Publication becomes an accretive process analogous to SpherePop histories rather than a stream optimized for novelty.

## 20.5 Interpretive Role

This critique extends the constraint-first paradigm into technological culture, arguing that sustainable information ecosystems must regulate transformation costs rather than reward unbounded amplification.

The next section presents the **Archival and Interpretive Work around Monica Anderson**, which explores dialogic knowledge systems and porous epistemic boundaries.

## 21 Archival and Interpretive Extensions: Dialogic Epistemology

### 21.1 Motivation

Alongside the formal and computational projects, a parallel effort engages with dialogic and model-free epistemological traditions associated with the work of Monica Anderson. This strand investigates knowledge formation not as theorem-proving or optimization but as iterative conversational stabilization within semi-permeable conceptual environments.

### 21.2 Leaking Chatroom

The “Leaking Chatroom” model describes discourse spaces whose boundaries allow gradual transfer of ideas without requiring full formalization.

Let  $\mathcal{D}_i$  denote participant knowledge states. Interaction is modeled as diffusion:

$$\partial_t \mathcal{D}_i = \sum_j k_{ij} (\mathcal{D}_j - \mathcal{D}_i),$$

analogous to entropy redistribution across conversational nodes.

Leakage is not loss but controlled permeability enabling convergence without collapse of diversity.

### 21.3 Reed Wall Mind

This concept characterizes cognition as a boundary that filters rather than blocks information. The wall is flexible: it attenuates signals while preserving structural coherence.

Mathematically, perception is represented as a filtered projection:

$$x_{\text{internal}} = \int G(x, y) x_{\text{external}}(y) dy,$$

with kernel  $G$  controlling permeability.

### 21.4 Motile Womb Theory

This metaphorical framework treats creative environments as mobile incubators of structure. Instead of static institutions, generative contexts move through conceptual space, carrying partially formed ideas.

Formally, one considers a moving viability region  $\mathcal{C}(t)$  within a larger conceptual manifold:

$$x(t) \in \mathcal{C}(t),$$

with  $\mathcal{C}$  evolving alongside the ideas it supports.

### 21.5 Archival Aim

The project preserves, interprets, and extends these epistemic models while relating them to the constraint-mediated dynamics explored elsewhere in the research program.

### 21.6 Interpretive Role

This strand demonstrates that conversational and experiential knowledge systems exhibit the same smoothing, bounded transformation, and metastability observed in physical and computational contexts.

## 22 Conclusion: A Program of Constraint-Mediated Structure

Across cosmology, mathematics, computation, governance, pedagogy, and narrative, the projects described here converge on a single structural thesis:

*Enduring structure emerges from bounded transformation, not unbounded optimization.*

The RSVP framework provides the physical exemplar, while derived geometry, rewriting systems, semantic calculi, civic designs, and epistemic models explore parallel realizations of the same principle. Each domain investigates how systems persist by redistributing tension under constraint rather than eliminating it.

The research program therefore does not seek a universal solution or final equilibrium. Its aim is to understand the conditions under which complex systems remain intelligible, repairable, and historically coherent while continually changing.



## References

- [1] Albert, D. Z. (2000). *Time and Chance*. Harvard University Press.
- [2] Anderson, P. W. (1972). More is Different. *Science*, 177(4047), 393–396.
- [3] Arnold, V. I. (1989). *Mathematical Methods of Classical Mechanics* (2nd ed.). Springer.
- [4] Barandes, J. A. (2023). Stochastic Mechanics Without Wavefunctions. *Physical Review A*, 107(5), 052203.
- [5] Batalin, I. A., & Vilkovisky, G. A. (1981). Gauge Algebra and Quantization. *Physics Letters B*, 102(1), 27–31.
- [6] Bennett, C. H. (1982). The Thermodynamics of Computation. *International Journal of Theoretical Physics*, 21(12), 905–940.
- [7] Bollobas, B. (1998). *Modern Graph Theory*. Springer.
- [8] Callen, H. B. (1985). *Thermodynamics and an Introduction to Thermostatistics* (2nd ed.). Wiley.
- [9] Carroll, S. (2010). *From Eternity to Here: The Quest for the Ultimate Theory of Time*. Dutton.
- [10] Deacon, T. W. (2011). *Incomplete Nature: How Mind Emerged from Matter*. W. W. Norton.
- [11] Dirac, P. A. M. (1930). *The Principles of Quantum Mechanics*. Oxford University Press.
- [12] Ellul, J. (1964). *The Technological Society*. Vintage.
- [13] Friedman, J. (1983). *Foundations of Space-Time Theories*. Princeton University Press.
- [14] Gromov, M. (1999). *Metric Structures for Riemannian and Non-Riemannian Spaces*. Birkhuser.
- [15] Haken, H. (1983). *Synergetics: An Introduction*. Springer.
- [16] Jaynes, E. T. (1957). Information Theory and Statistical Mechanics. *Physical Review*, 106(4), 620–630.

- [17] Jacobson, T. (1995). Thermodynamics of Spacetime: The Einstein Equation of State. *Physical Review Letters*, 75(7), 1260–1263.
- [18] Kauffman, S. A. (1993). *The Origins of Order*. Oxford University Press.
- [19] Keller, E. F. (1978). *Reflections on Gender and Science*. Yale University Press.
- [20] Kolmogorov, A. N. (1965). Three Approaches to the Quantitative Definition of Information. *Problems of Information Transmission*, 1(1), 1–7.
- [21] Landauer, R. (1961). Irreversibility and Heat Generation in the Computing Process. *IBM Journal of Research and Development*, 5(3), 183–191.
- [22] Lloyd, S. (2000). Ultimate Physical Limits to Computation. *Nature*, 406, 1047–1054.
- [23] Mac Lane, S. (1998). *Categories for the Working Mathematician* (2nd ed.). Springer.
- [24] May, R. M. (1976). *Simple Mathematical Models with Very Complicated Dynamics*. Princeton University Press.
- [25] Meadows, D. H., et al. (1972). *The Limits to Growth*. Universe Books.
- [26] Misner, C. W., Thorne, K. S., & Wheeler, J. A. (1973). *Gravitation*. W. H. Freeman.
- [27] Mumford, D. (1999). *The Red Book of Varieties and Schemes*. Springer.
- [28] Nicolis, G., & Prigogine, I. (1977). *Self-Organization in Nonequilibrium Systems*. Wiley.
- [29] Peirce, C. S. (1931–1958). *Collected Papers of Charles Sanders Peirce*. Harvard University Press.
- [30] Penrose, R. (1989). *The Emperor’s New Mind*. Oxford University Press.
- [31] Prigogine, I., & Stengers, I. (1984). *Order Out of Chaos*. Bantam.
- [32] Ruelle, D. (1991). *Chance and Chaos*. Princeton University Press.
- [33] Shannon, C. E. (1948). A Mathematical Theory of Communication. *Bell System Technical Journal*, 27, 379–423.
- [34] Smolin, L. (2006). *The Trouble with Physics*. Houghton Mifflin.
- [35] Strogatz, S. H. (1994). *Nonlinear Dynamics and Chaos*. Perseus Books.

- [36] Turing, A. M. (1936). On Computable Numbers, with an Application to the Entscheidungsproblem. *Proceedings of the London Mathematical Society*, 42(2), 230–265.
- [37] Ulanowicz, R. E. (1997). *Ecology, the Ascendent Perspective*. Columbia University Press.
- [38] Weinberg, S. (1972). *Gravitation and Cosmology*. Wiley.
- [39] Whitehead, A. N. (1929). *Process and Reality*. Macmillan.
- [40] Wiener, N. (1948). *Cybernetics*. MIT Press.
- [41] Zurek, W. H. (1989). Algorithmic Randomness and Physical Entropy. *Physical Review A*, 40(8), 4731–4751.