FIT (Force–Information–Time) Dynamics: Origin and Design Goals

A Constraint-Driven Lens on System Evolution

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Abstract

We present the Force–Information–Time (FIT) Framework, a minimal meta-theory for reasoning about evolutionary dynamics across physical, biological, cognitive, social, and artificial systems. Starting from a fundamental question—*why do hierarchical structures emerge, and why do systems fail not from lack of power but from wrong tempo?*—we compress "evolution" into three primitive variables: **Force (F)** as directed influence, **Information (I)** as persistent causal structure, and **Time (T)** as emergent characteristic scales. Extended with **Constraint (C)** and **State (S)**, these five primitives generate a level-aware framework that addresses the fragmentation problem in cross-domain evolutionary science.

Unlike domain-specific theories (thermodynamics, evolutionary biology, machine learning optimization), FIT provides a *meta-language*—a common syntax for expressing diverse evolutionary phenomena without claiming to replace specialized frameworks. The framework is explicitly designed to be: (1) **minimal**—using the fewest primitives without assuming specific mechanisms; (2) **operational**—every theoretical claim translatable to measurement protocols; (3) **falsifiable**—generating specific, testable propositions; and (4) **level-aware**—binding all statements to explicit estimator tuples.

We articulate six principles governing system evolution, distinguishing near-tautological core principles ($\mathscr{L}1$–$\mathscr{L}3$) from empirical working hypotheses ($\mathscr{H}4$–$\mathscr{H}6$), and derive 18 falsifiable propositions. The Estimator Selection Theory (EST) introduced in v2.4 provides formal axioms (A1–A8) preventing "estimator-hacking" critiques while acknowledging observer-dependence. Initial Tier-1 validation on cellular automata (Conway's Game of Life, Langton's Ant) demonstrates both predictive power and sensitivity to measurement choices.

This paper serves as the foundational reference for FIT, establishing the philosophical motivations, formal structure, and epistemological commitments of the framework. It is intended for researchers in philosophy of science, complex systems, and cross-disciplinary evolutionary theory.

Keywords: evolutionary dynamics, meta-theory, philosophy of science, complex systems, information theory, cross-scale emergence, axiomatic framework

Suggested Zenodo categories: History and Philosophy of Physics; Complex Systems; Philosophy of Science

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1. Introduction: The Unifying Question

1.1 Why F-I-T?

From quantum fluctuations to civilizational collapse, from molecular self-assembly to institutional decay, we observe the same patterns: hierarchical structures emerge, stabilize, transform, and sometimes catastrophically fail. The same question echoes across scales:

> *Why do clearly defined hierarchical structures emerge? Why does evolution often manifest as a repeating rhythm of "oscillation—stability—aggregation—re-stability"? Why do many systems fail not because of insufficient power or lack of information, but because the "pace of doing things" is wrong?*

This paper presents a framework that attempts to answer these questions in a unified way.

1.2 The Fragmentation Problem

Modern science approaches evolutionary phenomena through fragmented lenses:

Domain	Focus	Blind spots
Thermodynamics	Energy dissipation, entropy increase	Local entropy decrease in life
Information theory	Uncertainty reduction, channel capacity	Physical embedding, causal structure
Complexity science	Emergence, phase transitions	Post-transition dynamics
Evolutionary biology	Adaptation, selection	Non-biological evolution
Machine learning	Loss minimization, representation	Post-convergence regimes

While each framework succeeds within its domain, their mutual inconsistency impedes cross-disciplinary synthesis. Three illustrative tensions:

1. **Thermodynamic-informational tension**: The Second Law mandates entropy increase, yet biological and cognitive systems systematically reduce local entropy through information processing.

2. **Optimization endpoint ambiguity**: Gradient-following systems face the "what comes after convergence?" question. Does evolution terminate at local optima, continue indefinitely, or transition to qualitatively different dynamics?

3. **Scale-dependent laws**: The same system exhibits different apparent evolutionary laws at micro, meso, and macro scales. We lack a common language for when and how laws transform across scales.

These tensions signal the absence of **shared axioms** underlying all evolutionary domains.

1.3 The FIT Response

FIT compresses "evolution" into three minimal variables:

- **Force (F)**: The action that drives or constrains system change—interactions, selection pressures, institutional constraints, objective function gradients.

- **Information (I)**: Structures that can persist in time and produce causal effects—codes, forms, patterns, models, conventions.

- **Time (T)**: Not a background scale, but a spectrum of characteristic time scales (rhythms) emergent from the interaction of F and I.

FIT is a meta-framework, not a theory of a specific domain.

Its purpose: first reduce any problem of "evolution, development, origin, collapse, innovation" to `(F, I, T)`, then discuss levels, critical points, and transition paths.

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2. Philosophical Foundations

2.1 Epistemological Position

FIT adopts a **structural realist** stance: we commit to the reality of structural relations (constraints, information flow, force patterns) while remaining agnostic about the ultimate nature of entities. This allows cross-domain application without metaphysical overreach.

Key commitments:

1. **Observer-dependence acknowledged**: All propositions are bound to explicit estimator tuples. We do not claim observer-independent truths.

2. **Falsifiability required**: Every theoretical claim must be translatable to a measurement protocol with clear success/failure criteria.

3. **Minimalism preferred**: Use the fewest primitives without assuming specific mechanisms (e.g., natural selection) or substrates (e.g., carbon-based life).

2.2 What FIT Does NOT Claim

To set realistic expectations:

- ❌ FIT is a “theory of everything” for complex systems
- ❌ FIT replaces or subsumes existing frameworks (Free Energy Principle, Constructor Theory, etc.)
- ❌ All propositions have been validated across all domains
- ❌ FIT can predict exact trajectories of complex systems
- ❌ The five primitives are the only possible choice

What we DO claim:

- ✅ FIT provides a minimal meta-language for discussing evolution across domains
- ✅ The framework is falsifiable through computational and empirical experiments
- ✅ Initial validation shows promising results in controlled systems
- ✅ The estimator-awareness approach addresses a real methodological gap
- ✅ Applications to AI safety and complexity science are tractable

2.3 Relationship to Philosophy of Physics

FIT sits at the intersection of:

1. **Philosophy of physics**: Like thermodynamics, FIT seeks universal laws governing change, but without assuming physical substrate.

2. **Philosophy of biology**: Like evolutionary theory, FIT addresses adaptation and selection, but without assuming replicators or fitness functions.

3. **Philosophy of information**: Like information theory, FIT treats information as fundamental, but with explicit attention to physical embedding and causal structure.

4. **Systems theory**: Like cybernetics and general systems theory, FIT seeks cross-domain patterns, but with explicit falsifiability requirements.

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3. The Five Primitives

3.1 Force (F)

Definition: Any directed influence that tends to change system state.

$$F : \mathcal{S} \times T \to \mathbb{R}^n$$

Force as **generalized drift**:

$$\mathbb{E}[S_{t+1} - S_t \mid S_t] = \alpha F(S_t, t)$$

Key properties: - **Directionality**: F has magnitude and direction in state space - **Decomposability**: Multiple influences sum: $F_{\text{total}} = \sum_i F_i$ - **Scale-dependence**: Force at micro vs. macro levels may differ

Examples across domains: - Physics: $F = ma$ or $F = -\nabla V$ - Machine learning: $F = -\nabla L(w)$ (gradient descent) - Biology: Selection pressure, environmental stress - Social: Institutional constraints, market forces

3.2 Information (I)

Definition: Structures that persist in time and produce causal effects.

We distinguish: - **Entropy H(S)**: Uncertainty about system state - **Information gain I_{gain}**: Reduction in uncertainty

$$H(S_t) = -\sum_s P_t(s) \log P_t(s)$$

$$I_{\text{gain}}(P_0 \to P_1) := H(P_0) - H(P_1)$$

Key insight: Information is not merely "data" but **causally efficacious structure**—DNA sequences that direct protein synthesis, legal codes that constrain behavior, neural patterns that guide action.

3.3 Time (T)

Definition: An ordered index set providing sequencing of changes.

Critical distinction: Time in FIT is not merely a background parameter but a **characteristic scale spectrum** emergent from F-I interaction.

- Molecular vibrations: femtoseconds
- Neural processing: milliseconds
- Organismal development: years
- Civilizational cycles: centuries

Different levels have different "refresh rates"—and misalignment between these rates is a primary failure mode (see §6: Tempo Mismatch).

3.4 Constraint (C)

Definition: Reductions in accessible state space.

$$C(t) := \log |\mathcal{S}| - \log |\mathcal{S}_{\text{accessible}}(t)|$$

Interpretation: - $C(t) = 0$: Unconstrained (all states accessible) - $C(t)$ increases as accessible states shrink - Maximum: Only one state accessible ("frozen")

Constraints are **accumulated history**—each choice forecloses alternatives, each structure limits future possibilities.

3.5 State (S)

Definition: The complete specification of system configuration at time t.

$$S_t \in \mathcal{S}$$

State representation is observer-dependent: the "same" physical system admits multiple valid state descriptions at different levels of coarse-graining.

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4. Six Principles

FIT articulates six principles governing system evolution, explicitly distinguishing logical necessities from empirical hypotheses.

4.1 Core Principles (Near-Tautological)

$\mathscr{L}$1. Hierarchical Nesting

The world is composed of nested levels; each level emerges from information structures below and serves as platform for force and information above.

$\mathscr{L}$2. Cross-Level Transition

Bottom-up interactions can reach critical points where information structures undergo phase transitions, birthing new levels with new F-I-T coordinates.

$\mathscr{L}$3. Multi-Level Time Coupling

Evolution couples processes across fast and slow time scales; macro-evolution is a symphony of temporal rhythms.

4.2 Working Hypotheses (Empirical)

$\mathscr{H}$4. Cyclical Reinforcement

Force shapes information; stabilized information becomes a new force (constraint/driver), forming cycles: F → I → (new)F → (new)I…

$\mathscr{H}$5. Path Dependence

Evolutionary trajectories depend strongly on initial conditions and historical perturbations; history is irreversible.

$\mathscr{H}$6. Constraint Monotonicity (qualified)

Under effective closure, constraints tend to accumulate over time. *This requires specific scope conditions and may be violated locally.*

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5. Falsifiable Propositions

FIT generates 18 falsifiable propositions (detailed in v2.4 specification). Key examples:

P1 (Attractor Persistence): Stable states resist perturbation proportional to local constraint depth.

P2 (Constraint Monotonicity): Under closure, $\mathbb{E}[C(t+\Delta t)] \geq C(t)$.

P7 (Information Bounds): $I(t) \leq H_{\max} - C(t)$ at all times.

P10 (Estimator Coherence): Different admissible estimators yield correlated orderings.

P11 (Phase Transition): Systems exhibit discontinuous behavior change at critical constraint thresholds.

Each proposition is bound to explicit estimator tuples, with clear success/failure criteria.

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6. Why Tempo Matters

A central insight of FIT:

> **Many complex systems fail not because they lack power or information, but because high-impact changes become irreversible faster than the system can correct them.**

This "tempo mismatch" is formalized as:

$$\text{Validation Lag (VL)} := t_{\text{closure}} - t_{\text{effective}}$$

When VL exceeds correction timescales, systems enter **irreversible operation** regimes where errors accumulate beyond recovery.

Applications: - **AI Safety**: Self-modifying systems that update faster than human oversight - **Institutional Design**: Policies that lock in before evaluation completes - **Ecological Collapse**: Tipping points crossed before detection

FIT treats tempo (correction timescales) as a **first-class variable**, not an afterthought.

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7. Estimator Selection Theory (EST)

7.1 The Problem

A common critique of cross-domain frameworks: "You can always save the theory by changing estimators."

7.2 The Solution

EST provides formal axioms (A1–A8) specifying what makes an estimator "admissible":

- **A1 (Scope)**: Estimator must be defined for the declared system class
- **A2 (Robustness)**: Small input perturbations yield small output changes
- **A3 (Monotonicity)**: Ordinal relationships preserved under aggregation
- **A4 (Representation Invariance)**: Equivalent physical states yield equivalent estimates
- **A5 (P10 Coherence Gate)**: Must pass inter-estimator correlation test

- **A6 (Pre-registration)**: Estimator declared before data collection
- **A7 (Complexity Penalty)**: Simpler estimators preferred, ceteris paribus
- **A8 (Task-Typed Validity)**: Estimator appropriate for proposition type (ordinal/metric/topological)

This transforms FIT from “unfalsifiable framework” to “auditable measurement theory.”

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8. Initial Validation

8.1 Tier-1: Cellular Automata

Langton’s Ant (open boundary): - 97.5% theory-observation match for net displacement - Phase transition (P11) confirmed - Critical finding: Boundary conditions fundamentally affect dynamics

Conway’s Game of Life: - P7 (information bounds): 0% violations across 2,000 measurements - P10 (estimator coherence): $\rho = 0.775$ confirmed - P2 (constraint monotonicity): 19% violations—theory challenged under current estimator

8.2 Interpretation

The mixed results demonstrate FIT’s falsifiability: not all propositions pass all tests. The framework provides diagnostic tools (P10 coherence) to distinguish measurement failure from theoretical failure.

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9. Relationship to Existing Frameworks

Framework	Overlap	Distinction
Free Energy Principle	Information-theoretic, predictive	FIT is substrate-neutral, not brain-focused
Constructor Theory	Transformation-focused, counterfactual	FIT includes dynamics, not just possibility
Maximum Entropy Production	Thermodynamic, far-from-equilibrium	FIT includes information structure, not just dissipation
General Systems Theory	Cross-domain, hierarchical	FIT has explicit falsifiability, estimator theory
Category Theory	Structural, compositional	FIT is empirically oriented, not purely mathematical

FIT does not replace these frameworks but provides a **common syntax** for inter-translation.

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10. Limitations and Future Directions

10.1 Current Limitations

1. **Limited empirical validation**: Only Tier-1 (toy systems) completed
2. **Estimator development**: Admissible estimators not yet defined for all domains
3. **Quantitative predictions**: Framework yields qualitative/ordinal predictions, not precise numerical forecasts
4. **Scope boundaries**: Not clear where FIT fails to apply

10.2 Future Directions

1. **Tier-2 validation**: Real-world systems (markets, ecosystems, AI training)
2. **Domain-specific estimator libraries**: Physics, biology, social science
3. **Formal proofs**: Mathematical relationships between propositions
4. **Tool development**: Software for FIT-based analysis

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11. Conclusion

The Force–Information–Time Framework offers a minimal meta-language for evolutionary dynamics across scales and substrates. By compressing “evolution” into five primitives (F, I, T, C, S), articulating explicit principles, and generating falsifiable propositions bound to declared estimators, FIT addresses the fragmentation problem in cross-domain evolutionary science.

The framework’s central insight—that systems fail not from lack of power but from wrong tempo—has immediate applications to AI safety, institutional design, and complexity science.

FIT is offered not as dogma but as a candidate universal language, subject to continued testing and refinement.

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Appendix A: Version History

Version	Date	Changes
v1.0	Jan 2026	Initial foundational paper

Appendix B: Citation

```
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