Toward a Top-Level Ontology of Entropic Histories: A Scalar–Vector–Entropy Foundation for Ontology Engineering

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Abstract

Top-level ontologies such as the Basic Formal Ontology have demonstrated the importance of realist discipline in ontology engineering. However, their core primitives remain fundamentally static, treating entities as primary and processes as derivative. This limits their ability to represent irreversibility, historical dependence, semantic drift, and field-like phenomena now central to physics, computation, and cognition.

This paper proposes a new top-level ontology grounded in the Relativistic Scalar–Vector–Entropy Plenum (RSVP). Rather than taking entities as primitive, the proposed framework treats entropic histories, constrained flows, and stabilization regimes as fundamental. Objects, relations, agents, and information arise as low-entropy invariants within a dynamically constrained plenum.

The resulting ontology preserves realism while extending it beyond object-centric metaphysics, offering a unified foundation for physical, biological, cognitive, and computational domains.

1 Introduction

Top-level ontology engineering has reached a stage of maturity at which its central difficulties no longer concern representational convenience or modeling style, but the adequacy of its foundational primitives. Persistent problems surrounding irreversibility, ontology alignment, information, and agency suggest that existing frameworks are being pushed beyond the regimes for which they were designed [3, 2].

Realist top-level ontologies such as the Basic Formal Ontology (BFO) have demonstrated the importance of ontological discipline, particularly through careful distinctions between continuants and occurrents and a rejection of conceptualism [1, 5]. However, these frameworks remain fundamentally entity-centric. Objects are treated as ontologically primary, while processes, histories, and informational structures are introduced only secondarily. This orientation limits their expressive power in domains where irreversibility, historical dependence, and field-like dynamics are essential.

This paper advances the thesis that these limitations are not merely practical engineering challenges but reflect a deeper ontological misalignment. We argue that history, entropy, and constrained flow must be treated as ontologically primitive, and that entities should instead be understood as stabilized invariants arising within a dynamically constrained plenum.

To this end, we propose a new top-level ontology grounded in the Relativistic Scalar–Vector–Entropy Plenum (RSVP). The framework preserves realist commitments while extending ontology beyond static metaphysical atomism. It offers a unified foundation for physical, biological, cognitive, and computational domains, and provides principled explanations for both the success and failure modes of existing ontology engineering practices.

2 Limits of Entity-Centric Ontology

The motivation for a new top-level ontology arises from a cluster of persistent problems that resist resolution within entity-centric frameworks. These problems are often treated independently, but they share a common source: the assumption that entities are ontologically prior to histories, processes, and constraints.

First, entity-centric ontologies struggle to represent irreversibility as a constitutive feature of reality. Time is typically encoded as an ordering relation over entities or processes, rendering history descriptive rather than generative. This treatment is inadequate for domains in which path dependence is fundamental, including thermodynamics [10], biological development [14], learning systems [13], and computation itself. Irreversibility is not an accidental feature of these domains; it is central to their ontological structure.

Second, ontology interoperability relies heavily on mappings between independently developed ontologies. Empirically, such mappings are fragile and degrade under version drift. This fragility is often attributed to insufficient engineering effort, but it reflects a deeper issue. Static correspondences are being imposed on systems that evolve under incompatible dynamics. Without a shared dynamical substrate, mappings amplify entropy rather than reducing it, leading to semantic instability over time.

Third, the ontological status of information remains unresolved. Information is alternately treated as an abstract entity, a mental construct, or a property of physical artifacts [12]. Existing ontologies lack principled criteria for distinguishing informational structure from its physical carriers or symbolic representations. This ambiguity becomes acute in computational and cognitive domains, where informational patterns exert causal and normative force without being reducible to discrete objects.

Taken together, these difficulties indicate that entity primacy is an ontological liability. A framework that treats histories, constraints, and entropy as derivative cannot adequately represent domains in which stability itself must be explained.

3 Design Commitments

The RSVP ontology adopts a set of design commitments intended to preserve realist discipline while addressing the limitations identified above. These commitments are philosophical rather than methodological, and they constrain the choice of ontological primitives rather than modeling techniques.

First, the framework endorses realism without substance fixation. Reality exists independently of minds, but not all real structures are object-like. Stability, flow, and constraint may be ontologically fundamental even when no enduring entities can be identified.

Second, irreversibility is treated as primitive. Histories are not derived from entities; rather, entities arise as stabilized invariants over admissible histories. This reverses the explanatory direction characteristic of classical ontology.

Third, entropy is understood ontologically rather than epistemically. Entropy measures the degeneracy of admissible futures under constraint, not uncertainty in an observerâĂŹs knowledge. This interpretation aligns ontology with thermodynamic and informational considerations without collapsing into subjectivism [8, 11].

Fourth, the framework rejects conceptualism. Ontologies describe the structure of the world, not the structure of concepts in minds. Semantic stability is a property of constrained histories, not of linguistic conventions.

Finally, the framework is explicitly compositional across scales. Ontological structures must admit coherent coarse-graining and refinement, allowing stable subtheories to emerge within broader dynamical regimes.

4 The RSVP Framework

The RSVP ontology introduces three irreducible primitives: scalar density, vector flow, and entropy. These are not imported from physics as substantive claims, but are adopted as structural abstractions necessary to represent stability, directionality, and degeneracy across domains.

Scalar density, denoted Φ, represents ontic stability. Regions of high scalar density correspond to structures that persist under perturbation and maintain identity across admissible continuations. Such regions may correspond to particles, organisms, institutions, or persistent informational patterns, depending on scale and context.

Vector flow, denoted $\vec{v}$, represents directed constraint propagation. Causation, inference, control, and functional dependency are all treated as manifestations of vector flow. Relations are not primitive; they emerge as stable couplings of directed flows within constrained regions.

Entropy, denoted S, measures the degeneracy of admissible futures. Low entropy corresponds to constrained continuation and invariant structure, while high entropy corresponds to branching, instability, or interpretive ambiguity. Entropy thus provides a principled criterion for when identity and representation are sustainable.

These three primitives are mutually irreducible. Scalar density cannot be reduced to vector flow, as persistence is not equivalent to directionality. Vector flow cannot be reduced to entropy, as constraint propagation does not entail degeneracy. Entropy cannot be reduced to scalar density, as stability does not preclude multiplicity of futures. Classical ontologies implicitly assume low-entropy regimes in which these distinctions collapse; RSVP makes them explicit.

Together, $(\Phi, \vec{v}, S)$ define a dynamically constrained plenum in which ontological structure emerges historically. Entities, processes, relations, and information are not primitives but stabilized configurations within this plenum.

5 Event-Historical Semantics

The RSVP ontology is fundamentally history-first. This section makes that commitment explicit by introducing an event-historical semantics in which ontological structure is grounded in admissible histories rather than in static inventories of entities. The purpose of this semantics is not to replace existing logical or representational frameworks, but to supply the conditions under which such frameworks remain ontologically coherent.

A history is understood as an irreversible trajectory governed by constraints that regulate which continuations remain admissible. These constraints are not merely descriptive regularities but constitutive conditions that define the space of possible futures. A history, in this sense, is not a record of what has occurred, but a structured process of constraint satisfaction unfolding over time.

Formally, let $\mathcal{H}$ denote the space of all histories admissible under a given ontological regime. Admissibility is defined relative to constraint sets that may encode physical laws, biological organization, institutional rules, or semantic invariants. A history $h \in \mathcal{H}$ is admissible if and only if it admits at least one continuation consistent with these constraints. Irreversibility is primitive: histories compose forward in time, but do not admit nontrivial inverses.

Within this framework, entities are not taken as primitives but arise as equivalence classes over histories. Two histories are equivalent with respect to an entity if they preserve the same invariant structure across admissible continuations. Identity is therefore defined historically: an entity persists precisely when all admissible futures preserve the relevant invariants. This account explains why identity is robust in some domains and fragile in others, without appealing to metaphysical substance.

Entropy plays a central role in this semantics. Entropy measures the branching factor of admissible continuations from a given historical state. Low entropy corresponds to constrained continuation and stable invariants, while high entropy corresponds to proliferating futures and loss of structural coherence. Identity, reference, and representation are sustainable only in regimes where entropy remains bounded.

This event-historical perspective clarifies the ontological status of processes. Processes are not entities that happen to unfold in time; they are structured regions of history characterized by directed constraint propagation. Their ontological character is determined by how they restrict future admissibility, not by their decomposition into temporal parts.

The event-historical semantics thus reverses the explanatory order of classical ontology. Rather than deriving history from entities, it derives entities from history. Ontology, on this view, is the study of admissible trajectories and the conditions under which invariants emerge within them.

6 Ontology Mappings and Entropic Instability

Ontology mappings are commonly introduced as a solution to semantic heterogeneity. Within entity-centric frameworks, they are typically treated as static correspondences between classes, relations, or axioms. Empirically, however, such mappings are brittle. They require continual maintenance, degrade under version drift, and often collapse when ontologies evolve independently. The RSVP framework explains these failures as a consequence of entropic misalignment rather than engineering deficiency.

From an event-historical perspective, an ontology is not a static artifact but a constraint system governing admissible histories of representation and use. When two ontologies are developed independently, they typically impose distinct constraints on admissible histories. A mapping between them attempts to align these constraint systems. If the systems evolve under different dynamics, the space of admissible histories diverges, and the mapping ceases to preserve meaning.

Formally, a mapping between ontologies requires that admissibility be preserved under translation. That is, histories admissible under one ontology must map to histories admissible under the other. When entropy is low, admissible histories are tightly constrained, and such preservation is possible. When entropy increases, admissible histories branch, and preservation fails. The mapping does not merely become inaccurate; it amplifies entropy by introducing incompatible constraints.

This analysis explains why ontology mappings sometimes succeed in practice. Mappings are stable when both ontologies operate within low-entropy regimes, such as highly regulated scientific domains or narrowly defined institutional contexts. In such cases, admissible histories remain aligned, and translation preserves invariants. Outside these regimes, persistent mappings are structurally unstable.

The RSVP framework also clarifies the role of so-called upper ontologies as anchors. An upper ontology functions not by providing a neutral vocabulary, but by imposing strong constraints that reduce entropy across admissible histories. When successful, such anchoring effectively induces convergence toward a shared low-entropy regime. When unsuccessful, it becomes a source of friction rather than interoperability.

Importantly, the ideal outcome of ontology mapping is not perpetual translation but convergence. When two ontologies are successfully aligned, the result is not a stable mapping layer but the emergence of a new, unified constraint system under which both sets of practices become admissible. Mappings are therefore transitional structures whose success is marked by their eventual obsolescence.

By treating mappings as dynamical rather than static objects, RSVP provides a principled explanation for both their utility and their limits. Ontology engineering is revealed not as the construction of eternal correspondences, but as the management of entropy across evolving representational histories.

7 Embedding BFO as a Low-Entropy Subtheory

This section revisits the relationship between RSVP and established realist ontologies by providing a clean, non-redundant account of how a representative fragment of the Basic Formal Ontology (BFO) embeds within RSVP as a stabilized, low-entropy subtheory. The aim is neither to subsume BFO wholesale nor to critique its internal coherence, but to explain the conditions under which its categories are ontologically appropriate.

BFO is explicitly realist and entity-centric. Its core distinctions between continuants and occurrents, together with participation relations, presuppose the existence of stable identity conditions across time. These presuppositions are not trivial; they restrict the space of admissible histories to those in which identity-preserving continuations dominate. In RSVP terms, BFO operates entirely within regimes characterized by high scalar density and bounded entropy.

Within such regimes, continuants correspond to regions of the plenum that remain structurally invariant across admissible histories. Scalar density remains sufficiently high that perturbations do not induce branching that would undermine identity. Occurrents correspond to directed flows constrained by these regions, rather than to free-standing processes. Participation relations remain well-defined precisely because entropy remains low enough to prevent divergence of admissible continuations.

This interpretation explains both the strength and the scope limitations of BFO. In domains such as anatomy, materials science, and regulated institutional contexts, the assumption of low entropy is empirically justified. Structures persist, processes unfold in predictable ways, and participation relations can be treated as stable. In these contexts, BFOâĂŹs categories are not merely useful but ontologically appropriate.

However, the same assumptions become liabilities in domains characterized by rapid change, versioning, feedback, or learning. In such domains, admissible histories branch, scalar density fluctuates, and identity conditions erode. RSVP predicts that entity-centric ontologies will struggle in these regimes, not because they are poorly designed, but because the ontological conditions they presuppose no longer obtain.

The embedding of BFO within RSVP therefore preserves compatibility without reduction. RSVP does not reinterpret continuants as processes or dissolve entity ontology into flux. Instead, it explains why continuants exist when they do, and why they fail when entropy rises. BFO emerges as a special case within a broader ontological landscape rather than as a universal foundation.

This account also reframes debates about philosophical priority. Ontology does not bifurcate into philosophical versus engineering concerns. Rather, both are engaged in managing constraints over histories. BFOâĂŹs philosophical rigor reflects its commitment to low-entropy regimes; RSVP generalizes this rigor to domains where such regimes cannot be assumed.

8 Artificial Intelligence, Cognition, and Admissibility

Debates concerning artificial intelligence often conflate ontological questions with engineering speculation. The RSVP framework separates these issues by focusing on admissibility rather than mechanism. The central ontological question is not whether machines can replicate human cognition, but whether artificial systems can sustain histories exhibiting the stability, constraint propagation, and entropy management characteristic of cognitive agency.

Human cognition unfolds within a highly constrained historical regime. Biological organization, developmental history, and embodied interaction sharply restrict the space of admissible futures. These constraints yield stable identity, persistent agency, and coherent semantic reference. From an RSVP perspective, cognition corresponds to a region of elevated scalar density coupled with richly structured vector flows and tightly regulated entropy.

Claims that artificial general intelligence is impossible often rest on the assumption that these constraints are inseparable from biological substrate. RSVP does not adjudicate substrate dependence directly. Instead, it reframes the issue in terms of admissibility. If an artificial system can sustain a regime in which identity, agency, and semantic invariants remain stable across admissible histories, then ontological parity with cognition follows, regardless of implementation.

Conversely, fears that artificial systems will spontaneously acquire dangerous agency often ignore the difficulty of maintaining such regimes. High-capacity computation alone does not guarantee low entropy. Systems optimized for narrow tasks frequently operate in high-entropy representational regimes, exhibiting rapid branching of admissible behaviors and limited identity persistence. RSVP predicts that such systems will lack robust agency unless explicitly constrained.

This perspective also clarifies the role of training, alignment, and governance. Training procedures function as entropy-reduction mechanisms, shaping admissible histories by imposing gradients in the vector field. Alignment constraints operate by restricting continuation rather than by encoding static values. Failures of alignment are therefore best understood as failures of constraint maintenance under historical pressure.

Importantly, RSVP dissolves false analogies between intelligence and tools. Cars and weapons do not sustain histories with identity or agency; they remain low-scalar, low-agency structures embedded within human-controlled regimes. Artificial systems capable of autonomous adaptation occupy a fundamentally different ontological category, one defined by their capacity to regulate their own admissible futures.

By grounding analysis in admissibility rather than capability, RSVP provides a framework for discussing artificial cognition without appeal to hype or metaphysical speculation. Intelligence becomes a question of sustained constraint under entropy, not of mimicry or computational scale.

9 Conclusion: Ontology as Constraint on History

This paper has argued that the persistent difficulties encountered in ontology engineeringâĂŤirreversibility, mapping fragility, informational ambiguity, and regime mismatchâĂŤare not merely technical problems but symptoms of a deeper ontological misalignment. When entities are treated as ontologically primitive, history, constraint, and degeneration are forced into secondary roles, where they can be described but not explained. The result is an ontology that performs well only under narrow, implicitly assumed conditions of stability.

The RSVP framework proposes a reorientation. Rather than beginning with entities and attempting to account for change, RSVP begins with admissible histories and treats entities as stabilized invariants within constrained dynamical regimes. Scalar density captures persistence, vector flow captures directed constraint, and entropy captures the degeneracy of possible futures. Together, these primitives articulate the conditions under which identity, relation, agency, and information arise and persist.

This shift does not abandon realism. On the contrary, it strengthens realist ontology by grounding ontological categories in the structure of the world rather than in modeling convenience. Objects, processes, and relations remain real where they are stable, but their reality is explained rather than assumed. When stability fails, RSVP predicts ontological breakdown rather than treating it as modeling error.

The embedding of classical top-level ontologies such as BFO within RSVP demonstrates that this framework is not oppositional but generative. Entity- centric ontologies emerge as low-entropy subtheories, valid within domains where historical branching is limited and scalar density remains high. Their success and their limits are both explained by the same underlying principles. This account preserves interoperability without demanding universal uniformity.

Formally, the adjunction between histories and field regimes establishes that event-historical and field-theoretic descriptions are dual representations of the same ontological structure. Ontological disagreement is thus reinterpreted as disagreement over constraint placement, scale of abstraction, or entropy tolerance, rather than as disagreement over what exists. This reframing dissolves many long-standing disputes by revealing their structural commonality.

In application to artificial intelligence and cognition, RSVP provides a sober alternative to both optimism and alarmism. Intelligence is not a substance or a capability threshold, but a regime of sustained constraint under entropy. Artificial systems may or may not enter such regimes, depending not on scale alone but on their capacity to regulate admissible futures. This perspective reconnects debates about intelligence, alignment, and agency to ontological conditions rather than speculative narratives.

The broader implication is that ontology engineering must move beyond static taxonomies toward frameworks capable of representing irreversibility and historical dependence as first-class features. RSVP offers one such framework. It does not prescribe a single modeling language, nor does it replace existing ontologies. Instead, it provides a principled account of when ontological categories stabilize, when they fail, and why.

Ontology, on this view, is not merely a catalog of what exists. It is a theory of which histories remain admissible under constraint. To practice ontology engineering responsibly is therefore to manage not only symbols and categories, but the conditions under which meaning, identity, and agency can persist through time.

A Formal Foundations of Entropic Histories and RSVP Fields

This appendix provides a formal mathematical foundation for the ontology developed in the main text. Its purpose is to render precise the notions of admissible history, ontological entropy, stabilization, and the scalar–vector field representation that underwrite the RSVP framework. The presentation is intentionally domain-neutral. No appeal is made to specific physical laws, biological mechanisms, or computational architectures. The results concern only the structure of irreversibility, constraint, and persistence.

A.1 Histories and Admissibility

Let Ω denote the space of all possible event sequences. An element of Ω is a totally ordered sequence of events $(e_1 \prec e_2 \prec \cdots)$, where the ordering relation is primitive and irreversible. No inverse operation is assumed to exist that would recover prior events from later ones.

A history is defined as a finite or infinite prefix of such a sequence. If h and h' are histories, then $h \preceq h'$ denotes that h is a prefix of h'. This relation induces a partial order on histories corresponding to irreversible temporal extension.

Ontological coherence is imposed by admissibility constraints. An admissibility constraint is a predicate $C : \Omega \to \{0, 1\}$ that evaluates whether a given event sequence is permitted under the ontology in question. These constraints are not epistemic; they do not represent what is known or believed, but rather what is allowed to occur without violating identity conditions, causal consistency, semantic integrity, or other ontological requirements.

A history h is said to be admissible if $C(h) = 1$ and if there exists at least one extension $h' \succeq h$ such that $C(h') = 1$. The second condition ensures that admissible histories are not terminal dead ends. Ontologies that permit histories with no admissible continuation are ontologically degenerate in the sense relevant here.

The set of all admissible histories is denoted by $\mathcal{H} \subseteq \Omega$. It is this space, rather than a set of entities, that serves as the ontological base of the RSVP framework.

A.2 Entropy as Degeneracy of Futures

Given an admissible history $h \in \mathcal{H}$, define its admissible future set by

$$\mathrm{Fut}(h) = \{h' \in \mathcal{H} \mid h \preceq h'\}.$$

This set represents the total space of ontologically permitted continuations of h.

The entropy of a history h is defined as

$$S(h) = \log |\mathrm{Fut}(h)|,$$

with the understanding that $S(h)$ may be infinite. This definition measures the degeneracy of admissible futures rather than uncertainty or lack of knowledge. A history with low entropy admits few coherent continuations; a history with high entropy admits many mutually divergent ones.

The role of entropy in ontology is structural. Identity, persistence, and invariance require that admissible futures remain sufficiently constrained. If $S(h)$ is unbounded, then no criterion of persistence can remain invariant across all admissible extensions of h.

[Entropy Bound for Identity] If a structure admits a well-defined identity criterion across all admissible extensions of a history h, then $S(h)$ must be bounded.

Proof. Assume that $S(h)$ is unbounded. Then for any proposed identity criterion, there exist admissible extensions of h that diverge arbitrarily with respect to that criterion. Since identity must be preserved across all admissible futures, no such criterion can remain invariant. Therefore bounded entropy is a necessary condition for identity. $\square$

A.3 Scalar Density and Stabilization

Persistence is formalized via scalar density. Let R denote a region or pattern within a history h. The scalar density $\Phi(R, h)$ is defined as the infimum, over all admissible extensions $h' \in \mathrm{Fut}(h)$, of an invariance measure $\mathrm{Inv}(R, h')$ that quantifies the degree to which R remains structurally intact under continuation.

Intuitively, $\Phi(R, h)$ measures how robust a structure is against admissible historical extension. High scalar density corresponds to strong persistence; low scalar density corresponds to fragility or transience.

A structure R is said to be stabilized at history h if there exist thresholds $\Phi_{\min}$ and $S_{\max}$ such that $\Phi(R, h) \geq \Phi_{\min}$ and $S(h|_R) \leq S_{\max}$. Stabilized structures are those that remain recognizably the same across admissible futures. These structures correspond to what classical ontologies describe as continuants.

A.4 Vector Flow and Directional Constraint

Change and process are captured through directional constraint propagation. Let $f : h \to h'$ denote an admissible extension of a history. The vector field $\vec{v}$ assigns to each event e a directional influence on future admissibility, formally represented as the sensitivity of the constraint predicate with respect to that event.

Nonzero $\vec{v}$ indicates that the occurrence of an event biases or directs the space of admissible futures. A process corresponds to a coherent trajectory through history along which $\vec{v}$ remains consistently oriented. Unlike scalar density, which measures persistence, vector flow measures transformation and propagation.

A.5 The History–Field Correspondence

The RSVP framework relates histories to field configurations through abstraction. Given a history $h \in \mathcal{H}$, define a mapping

$$F(h) = (\Phi_h, \vec{v}_h, S_h),$$

where Φ_h encodes persistence of invariants across admissible futures, $\vec{v}_h$ encodes directional constraint propagation, and S_h encodes the degeneracy of admissible continuations.

Distinct histories may map to the same field configuration when their differences are irrelevant at the chosen scale. The field representation is therefore a coarse-graining of historical detail.

Conversely, a field configuration $(\Phi, \vec{v}, S)$ determines a family of admissible histories. Define

$$G(\Phi, \vec{v}, S) = \{h \in \Omega \mid h \text{ respects all field bounds}\}.$$

A history respects a field regime if it remains within scalar stability thresholds, follows allowed vector directions, and does not exceed entropy bounds.

A.6 Adjunction Between Histories and Fields

The mappings F and G form an adjoint pair. Abstraction from histories to fields is left adjoint to realization from fields to histories.

[History–Field Adjunction] For any history h and any field regime r, the condition that $F(h)$ refines r is equivalent to the condition that $h \in G(r)$. Consequently, $F \dashv G$.

Proof. If $F(h)$ refines r, then the scalar, vector, and entropy characteristics induced by h satisfy all constraints imposed by r, and thus h is an admissible realization of r. Conversely, if $h \in G(r)$, then the field configuration induced by h cannot violate the constraints of r, and hence $F(h)$ refines r. The correspondence is natural and satisfies the unit and counit conditions of an adjunction. □

This adjunction establishes that event-historical and field-theoretic descriptions encode the same ontological content. They differ only in whether constraint is represented dynamically through history or statically through fields.

A.7 Ontological Consequences

The formalism developed here implies that histories, not entities, are ontologically primary. Entities arise as stabilized equivalence classes of histories under bounded entropy. Ontological failure corresponds to entropy divergence, and abstraction corresponds to passage to field-level description.

B A Worked Example: Ontology Versioning and Entropic Divergence

This appendix presents a concrete worked example illustrating how the RSVP framework analyzes ontology evolution and explains the empirical instability of persistent ontology mappings. The example is intentionally abstracted from any particular domain ontology, so that the analysis applies equally to biomedical, institutional, and computational settings.

B.1 Ontology Versions as Histories

Let $\mathcal{O}_0$ denote an initial ontology at time t_0. We treat $\mathcal{O}_0$ not as a static artifact, but as the initial prefix of a history in the space Ω of possible ontology-development event sequences. Events include the introduction of new classes, refinement of definitions, addition or removal of axioms, and changes in modeling conventions.

A versioned ontology $\mathcal{O}_t$ at time t corresponds to a history

$$h_t = (e_1 \prec e_2 \prec \cdots \prec e_t),$$

where each event e_i is an ontological modification. Ontology evolution is therefore represented as irreversible extension in the prefix order on histories.

Admissibility constraints C encode conditions such as logical consistency, alignment with intended domain interpretation, and conformance to governance rules. An ontology version $\mathcal{O}_t$ is admissible if and only if the corresponding history h_t satisfies C and admits at least one coherent extension.

B.2 Admissible Futures and Ontological Entropy

Given an admissible ontology version $\mathcal{O}_t$, the set of admissible future versions is given by

$$\mathrm{Fut}(h_t) = \{h_{t'} \mid t' \geq t \text{ and } C(h_{t'}) = 1\}.$$

This set includes all ways in which the ontology may evolve without violating its constraints.

The ontological entropy at version t is defined as

$$S(h_t) = \log |\mathrm{Fut}(h_t)|.$$

Low entropy corresponds to a tightly governed ontology with limited permissible change. High entropy corresponds to an ontology whose future evolution is weakly constrained, allowing divergent modeling choices, incompatible extensions, or semantic drift.

B.3 Scalar Density and Ontological Stability

Let R be a representational structure within $\mathcal{O}_t$, such as a core class hierarchy or foundational distinction. The scalar density $\Phi(R, h_t)$ measures the persistence of R across admissible future versions. Formally, $\Phi(R, h_t)$ is the infimum, over all $h_{t'} \in \mathrm{Fut}(h_t)$, of an invariance measure that compares the interpretation of R in $\mathcal{O}_t$ and $\mathcal{O}_{t'}$.

When $\Phi(R, h_t)$ is high, the structure R remains stable across versioning. When $\Phi(R, h_t)$ is low, small changes in the ontology may radically alter the role or meaning of R.

Foundational ontologies such as BFO aim to maximize Φ for a small set of core distinctions by enforcing strict admissibility constraints. Rapidly evolving application ontologies typically tolerate lower scalar density in exchange for expressive flexibility.

B.4 Ontology Mappings as Synchronization Operators

Consider two ontologies $\mathcal{O}_t^A$ and $\mathcal{O}_t^B$ evolving independently from a common ancestor. A mapping M_t between them is intended to align corresponding structures at time t. Formally, M_t is a relation between histories h_t^A and h_t^B that preserves admissibility-relevant structure.

For a mapping to remain valid across time, it must preserve admissibility under extension. That is, for every admissible extension $h^A_{t'} \succeq h^A_t$, there must exist a corresponding admissible extension $h^B_{t'} \succeq h^B_t$ such that the mapping relation is preserved.

B.5 Entropy Amplification and Mapping Failure

We now show that persistent mappings are generically unstable under entropy growth.

[Mapping Instability Under Entropy Growth] Let $\mathcal{O}^A_t$ and $\mathcal{O}^B_t$ be independently evolving ontologies with admissible histories h^A_t and h^B_t. If either $S(h^A_t)$ or $S(h^B_t)$ grows without bound, then no mapping M_t can remain valid across all admissible extensions.

Proof. Assume without loss of generality that $S(h^A_t)$ is unbounded. Then the set of admissible futures $\mathrm{Fut}(h^A_t)$ contains arbitrarily many mutually divergent extensions. Any mapping M_t selects a correspondence between structures in $\mathcal{O}^A_t$ and $\mathcal{O}^B_t$.

For M_t to remain valid, every admissible extension of h^A_t must correspond to an admissible extension of h^B_t that preserves the mapped structure. Since $\mathcal{O}^B_t$ evolves independently, its admissible futures cannot track all divergent branches of $\mathrm{Fut}(h^A_t)$. Therefore there exists an admissible extension of h^A_t for which no corresponding extension of h^B_t preserves M_t. Hence M_t fails to remain valid. □

This result explains the empirical fragility of ontology mappings without appealing to poor engineering practice. Mapping instability is a structural consequence of entropy divergence.

B.6 Low-Entropy Regimes and Temporary Synchronization

Mappings may nevertheless succeed temporarily in low-entropy regimes. If both $S(h^A_t)$ and $S(h^B_t)$ are bounded and if scalar density is high for the mapped structures, then admissible futures remain sufficiently aligned to permit synchronization.

In such cases, mappings function as dissipative operators. They reduce local entropy by enforcing convergence between histories. Once convergence is achieved, the mapping becomes redundant. This explains why successful mappings often disappear in mature systems, having been replaced by a unified or shared ontology.

B.7 Interpretation

The worked example demonstrates that ontology versioning is naturally modeled as irreversible history extension and that mapping instability follows from entropy growth rather than from conceptual error. RSVP provides a principled explanation for why foundational ontologies emphasize stability, why application ontologies exhibit drift, and why mappings are inherently provisional.

This example also clarifies the role of governance. Tight governance corresponds to entropy suppression and scalar stabilization. Agile development corresponds to tolerating higher entropy. RSVP does not privilege either strategy; it renders their tradeoffs explicit.

The example thus shows how abstract RSVP primitives yield concrete explanatory and predictive insight when applied to real ontology-engineering practice.

C Categorical Structure of Entropic Histories and Field Regimes

This appendix provides a categorical reconstruction of the RSVP ontology. The goal is to show that the history-based and field-based descriptions introduced in the main text arise as dual presentations of a single underlying structure. The categorical formulation clarifies compositionality, irreversibility, and stability, and it makes precise the sense in which classical ontologies appear as reflective substructures.

C.1 The Category of Admissible Histories

Let **Hist** denote a category whose objects are admissible histories $h \in \mathcal{H}$. A morphism $f : h \to h'$ exists if and only if $h \preceq h'$ and h' is an admissible extension of h. Composition is given by concatenation of extensions, and identity morphisms correspond to trivial extensions.

By construction, **Hist** is not a groupoid. Except for identities, its morphisms are non-invertible. This categorical asymmetry encodes irreversibility as a structural feature rather than as an external axiom.

Limits in **Hist** correspond to greatest lower bounds of compatible histories when such bounds exist. Colimits correspond to consistent amalgamation of histories under shared prefixes, though colimits are generally obstructed by entropy growth.

C.2 The Category of RSVP Field Regimes

Let **Field** denote a category whose objects are RSVP field configurations $(\Phi, \vec{v}, S)$ satisfying global admissibility conditions. A morphism $\alpha : r \to r'$ between field regimes exists when r' is a coarse-graining or relaxation of r that preserves admissibility. Intuitively, α forgets fine-grained structure while maintaining stability bounds.

Morphisms in **Field** are generally many-to-one. They encode abstraction, scale change, and representational forgetting. Identity morphisms correspond to exact preservation of field structure.

C.3 The Abstraction Functor

Define a functor F : **Hist** $\to$ **Field** by assigning to each history h the minimal field regime $F(h)$ that preserves all admissibility relations induced by h. On morphisms, F maps an extension $h \preceq h'$ to the induced refinement relation between $F(h)$ and $F(h')$.

The functor F is covariant. It preserves composition and identities by construction. Conceptually, F performs abstraction: it forgets historical detail while retaining exactly those constraints required to characterize admissibility.

C.4 The Realization Functor

Define a functor G : **Field** $\to$ **Hist** by assigning to each field regime r the collection of histories admissible under the constraints imposed by r. This assignment is functorial when histories are ordered by prefix extension and field morphisms correspond to relaxation of constraints.

The functor G expands abstract constraint into concrete realization. It is right-adjoint in character, as it freely generates admissible histories subject to given bounds.

C.5 Adjunction and Its Proof

[History–Field Adjunction] The functors $F : \mathbf{Hist} \to \mathbf{Field}$ and $G : \mathbf{Field} \to \mathbf{Hist}$ form an adjoint pair, with F left adjoint to G.

Proof. Let h be an object of **Hist** and let r be an object of **Field**. A morphism $F(h) \to r$ in **Field** exists if and only if the field regime induced by h refines the constraints of r. This condition holds precisely when h is admissible under r, which is equivalent to the existence of a morphism $h \to G(r)$ in **Hist**.

This correspondence is natural in both h and r. The unit of the adjunction maps each history to its canonical realization under its induced field regime. The counit maps each field regime to the abstraction of its realized histories. The triangle identities follow from minimality of abstraction and maximality of realization. □

The adjunction formalizes the claim that histories and fields encode the same ontological content at different levels of description. Disputes between history-first and structure-first ontologies thus reduce to representational preference rather than metaphysical disagreement.

C.6 Low-Entropy Subcategories

Within **Field**, consider the full subcategory $\mathbf{Field}_{\mathrm{low}}$ consisting of field regimes whose entropy is uniformly bounded and whose scalar density exceeds a fixed threshold. Objects of $\mathbf{Field}_{\mathrm{low}}$ correspond to stable regimes in which identity conditions are preserved across admissible realizations.

The inclusion functor $i : \mathbf{Field}_{\mathrm{low}} \hookrightarrow \mathbf{Field}$ admits a left adjoint.

Proof. Given an arbitrary field regime r, define $L(r)$ to be the maximal subregime of r obtained by suppressing all degrees of freedom that contribute to unbounded entropy or scalar instability. This construction yields a universal arrow from r to $\mathbf{Field}_{\mathrm{low}}$, establishing reflectivity. □

Reflectivity explains why entity-centric ontologies appear rigid. They operate entirely within $\mathbf{Field}_{\mathrm{low}}$, implicitly projecting richer field structure into stabilized subcategories.

C.7 Ontology Mappings as Spans

Ontology mappings may be represented categorically as spans in **Field**. A mapping between regimes r_1 and r_2 is a diagram $r_1 \leftarrow m \to r_2$, where m is a mediating regime encoding shared constraints.

[Non-existence of Persistent Mediators] If either r_1 or r_2 lies outside $\mathbf{Field}_{\mathrm{low}}$, then no universal mediating object m exists.

Proof. Outside $\mathbf{Field}_{\mathrm{low}}$, entropy is unbounded and admissible realizations diverge. Any candidate mediator would fail to preserve admissibility across all realizations, violating universality. Hence no such object exists. □

This result recovers the mapping instability theorem of Appendix B in categorical form.

C.8 Symbolic Ontologies as Presentations

Symbolic ontologies expressed in OWL or first-order logic correspond to presentations of objects in $\mathbf{Field}_{\text{low}}$. Their axioms define generators and relations sufficient to describe stabilized regimes, but they cannot present arbitrary objects of **Field**.

This explains categorically why symbolic ontologies succeed in stable domains and fail in highly dynamic ones. The failure is not logical but ontological: the objects being modeled lie outside the reflective subcategory.

C.9 Interpretive Summary

The categorical reconstruction establishes that irreversibility corresponds to non-invertibility of morphisms, abstraction corresponds to left adjoints, stability corresponds to reflectivity, and ontology engineering corresponds to navigation within and between entropy-bounded subcategories. The RSVP ontology thus admits a fully compositional semantics without reifying entities as primitive objects.

D A Worked Biological Example: Cell Lineages as Entropic Histories

This appendix develops a worked biological example demonstrating how the RSVP ontology analyzes persistence, differentiation, and identity in a concrete setting. The example is intentionally minimal and abstract. No specific molecular mechanisms are assumed. The analysis concerns only lineage structure, irreversibility, and admissible continuation.

D.1 Lineages as Histories

Consider a single biological cell at an initial developmental time t_0. Let e_0 denote the event corresponding to the existence of this cell. As the cell divides, differentiates, or undergoes apoptosis, each such change is represented as an irreversible event extending the developmental history.

A cell lineage is therefore represented as a history

$$h_t = (e_0 \prec e_1 \prec e_2 \prec \cdots \prec e_t),$$

where each e_i corresponds to a developmental event. The prefix order on histories captures the fact that later developmental states presuppose earlier ones and cannot be reversed.

Admissibility constraints encode biological coherence. Examples include viability, compatibility with developmental programs, and conservation of lineage continuity. A lineage history is admissible if it satisfies these constraints and admits further viable continuation.

D.2 Admissible Futures and Developmental Entropy

Given an admissible lineage history h_t, define the set of admissible future lineages

$$\mathrm{Fut}(h_t) = \{h_{t'} \mid t' \geq t \text{ and } h_{t'} \text{ is viable}\}.$$

The entropy of the lineage at time t is given by

$$S(h_t) = \log |\mathrm{Fut}(h_t)|.$$

Early in development, entropy is typically high. A pluripotent cell admits many distinct admissible futures corresponding to divergent differentiation pathways. As development proceeds, admissibility constraints narrow the space of futures, and entropy decreases.

D.3 Scalar Density and Cellular Identity

Let R denote a structural pattern corresponding to a cell type, such as epithelial or neuronal identity. Scalar density $\Phi(R, h_t)$ measures the degree to which this identity persists across admissible future histories.

In early development, $\Phi(R, h_t)$ is low for most specialized cell types, because admissible futures include differentiation into many alternative types. As differentiation proceeds, admissibility constraints restrict futures, and $\Phi(R, h_t)$ increases for the realized cell type.

Cellular identity is therefore not primitive. It emerges when scalar density exceeds a threshold and entropy falls below a bound. A differentiated cell type corresponds to a stabilized region of history in which identity is preserved across admissible continuation.

D.4 Vector Flow and Developmental Directionality

Development is not merely constraint narrowing but also directional. Certain events bias future admissibility strongly toward specific outcomes. This bias is captured by the vector field $\vec{v}$, which assigns to each developmental event a directional influence on future lineage structure.

For example, commitment to a germ layer induces a strong directional constraint that suppresses entire classes of admissible futures. This manifests as a nonzero vector flow that channels development along a restricted trajectory.

Processes such as differentiation correspond to coherent trajectories along which $\vec{v}$ remains consistently oriented. Dedifferentiation, where it occurs, corresponds to partial reversal of constraint, but never to full inversion of history.

D.5 Identity Preservation and Entropy Bounds

We now formalize the emergence of cell identity.

[Emergence of Cell Identity] A cell type supports a stable identity across development if and only if the entropy of its lineage history is bounded below a critical threshold.

Proof. If entropy is unbounded, admissible futures diverge across incompatible cell types, and no identity criterion can remain invariant. Conversely, if entropy is bounded and scalar density remains high, admissible futures preserve the same structural pattern, yielding a stable cell identity. □

This result explains why early embryonic cells lack stable identity, while differentiated cells possess it, without appealing to intrinsic essences.

D.6 Continuants and Occurrents Revisited

In this example, the classical distinction between continuants and occurrents arises naturally. A cell, once differentiated, behaves as a continuant because its scalar density is high and its entropy is low across admissible futures. Developmental processes behave as occurrents because they correspond to directed vector flow through history.

The distinction is therefore emergent rather than axiomatic. It depends on the regime of entropy and stability rather than on primitive ontological categories.

D.7 Ontological Breakdown and Plasticity

Pathological or experimentally induced plasticity corresponds to entropy increase. When admissibility constraints are relaxed, such as in induced pluripotency, the entropy of the lineage increases and scalar density of prior identity decreases. Identity breakdown is thus an ontological consequence of constraint relaxation rather than a metaphysical anomaly.

This explains why attempts to impose rigid identity categories on highly plastic biological systems often fail. The failure is not empirical but ontological: the systems lie outside low-entropy regimes.

D.8 Interpretation

The cell lineage example demonstrates that RSVP primitives are not abstractions detached from biology. They capture precisely the structural features that determine when identity, persistence, and process distinctions are coherent.

The example also illustrates the central thesis of the paper: ontological categories emerge from constrained histories rather than being imposed a priori. Biological identity is not a primitive fact but a stabilized historical regime.

This conclusion generalizes beyond biology. Any system exhibiting irreversible development, constraint propagation, and branching futures will exhibit the same ontological structure. RSVP provides a unified language for describing such systems across domains.

E Complexity, Decidability, and the Limits of Symbolic Reasoning

This appendix analyzes the computational properties of reasoning within the RSVP ontology. The aim is to clarify which forms of reasoning are decidable, which are tractable, and which are provably intractable or ill-posed. The analysis explains why symbolic ontologies succeed in low-entropy regimes and fail systematically outside them.

E.1 Reasoning as Constraint Satisfaction over Histories

Reasoning in the RSVP framework is fundamentally the problem of determining whether a given partial history admits at least one admissible continuation. Formally, given a history prefix $h \in \Omega$ and a constraint predicate C, the basic decision problem is whether there exists an extension $h' \succeq h$ such that $C(h') = 1$.

This problem generalizes classical satisfiability. In place of static models, one reasons over irreversible extensions. In place of truth in a structure, one reasons over admissibility of futures.

[Historical Satisfiability] A history prefix h is historically satisfiable if $h \in \mathcal{H}$.

Determining historical satisfiability is the most primitive reasoning task in RSVP. All higher-level reasoning tasks reduce to this problem under suitable encodings.

E.2 Undecidability in the General Case

In the general case, historical satisfiability is undecidable.

[Undecidability of General Historical Satisfiability] There exists a class of admissibility constraints C for which the problem of determining whether $h \in \mathcal{H}$ is undecidable.

Proof. Let C encode the halting condition of a Turing machine, where events correspond to computation steps and admissibility requires non-halting. A history prefix is admissible if and only if the encoded machine does not halt. Determining whether a given prefix admits continuation is therefore equivalent to the halting problem, which is undecidable. □

This result establishes that RSVP is not designed to support complete reasoning in full generality. Any ontology capable of expressing irreversible computation inherits this limitation.

E.3 Entropy Bounds and Decidable Subtheories

Decidability is recovered under entropy bounds.

[Entropy-Bounded Regime] A regime is entropy-bounded if there exists a finite constant K such that $S(h) \leq K$ for all admissible histories h in the regime.

Entropy-bounded regimes admit only finitely many admissible futures at each history prefix.

[Decidability under Entropy Bounds] If an ontology operates entirely within an entropy-bounded regime and all admissibility constraints are recursively enumerable, then historical satisfiability is decidable.

Proof. If entropy is bounded, then for any history prefix h the set $\mathrm{Fut}(h)$ is finite. Since admissibility constraints are recursively enumerable, one may enumerate all admissible extensions and determine whether any exist. Termination is guaranteed by finiteness. □

This theorem provides the formal justification for the success of symbolic ontologies in stable domains. Entropy bounds correspond precisely to the conditions under which reasoning terminates.

E.4 First-Order Logic as a Low-Entropy Fragment

First-order logic presupposes stable identity, fixed relations, and a finite model-theoretic horizon for reasoning. These presuppositions are satisfied exactly when entropy is bounded and scalar density remains high.

[Soundness of First-Order Reasoning] First-order reasoning over an ontology is sound if and only if the ontology corresponds to a low-entropy RSVP regime.

Proof. Soundness requires that predicates denote invariant structures across all admissible interpretations. This invariance holds precisely when admissible futures do not branch beyond a bounded set. Unbounded entropy introduces divergent interpretations that invalidate fixed predicate meaning. □

This result explains why first-order and description-logic ontologies degrade under version drift, rapid conceptual change, or socio-technical feedback.

E.5 OWL and Description Logics

OWL reasoning is decidable by design, but this decidability is achieved by restricting expressiveness. From the RSVP perspective, these restrictions correspond to implicit entropy bounds. OWL ontologies describe stabilized subtheories in which identity and participation relations remain invariant.

When OWL ontologies are applied to domains with high entropy, the result is not logical inconsistency but ontological mismatch. The domain violates the regime assumptions under which OWL reasoning is sound.

E.6 Complexity of Reasoning

Even within entropy-bounded regimes, reasoning complexity may be high.

[Complexity Lower Bound] There exist entropy-bounded RSVP regimes for which historical satisfiability is NP-complete.

Proof. Encode Boolean satisfiability as an admissibility constraint over histories with bounded branching. Each assignment corresponds to an admissible future. Checking whether any admissible future exists is equivalent to SAT. □

This result aligns RSVP with known complexity bounds in symbolic reasoning. It also clarifies that RSVP does not simplify reasoning; it explains why reasoning is difficult.

E.7 Implications for Ontology Engineering

The complexity results establish that ontology engineering cannot eliminate computational hardness. What it can do is control regime conditions. By maintaining low entropy and high scalar density, ontology engineers ensure that reasoning remains decidable and tractable.

When such conditions cannot be maintained, symbolic reasoning must be augmented or replaced by historical, probabilistic, or simulation-based methods. RSVP provides criteria for determining when such transitions are necessary.

E.8 Interpretation

This appendix completes the formal justification for RSVPâĂŹs layered view of ontology. Symbolic logics are not rejected; they are localized. Their success is explained by entropy suppression, and their failure is explained by entropy divergence.

Ontology engineering, on this view, is not primarily about choosing the right logic, but about managing the historical and entropic conditions under which logic remains meaningful.

F Basic Formal Ontology as a Conservative Low-Entropy Fragment of RSVP

This appendix establishes a precise formal relationship between the RSVP ontology and classical realist top-level ontologies, using Basic Formal Ontology (BFO) as a representative case. The main result is that BFO may be interpreted as a conservative fragment of RSVP, valid within entropy-bounded regimes. The proof clarifies both the strengths and the limitations of entity-centric realism.

F.1 The Target Fragment of BFO

We consider a core fragment of BFO sufficient to capture its foundational commitments. This fragment includes the distinction between independent continuants and occurrents, the dependence relations between them, and the participation relation linking continuants to occurrents. We do not consider domain-specific extensions or higher-order constructs.

Let **BFO** denote the theory axiomatizing this fragment in a standard first-order or description-logic presentation. Models of **BFO** consist of a domain of entities partitioned into continuants and occurrents, together with relations satisfying the usual axioms of persistence and participation.

F.2 RSVP Low-Entropy Regimes

Let $\mathbf{RSVP}_{\text{low}}$ denote the class of RSVP field regimes $(\Phi, \vec{v}, S)$ such that entropy is uniformly bounded and scalar density exceeds a fixed positive threshold across all admissible histories. Within such regimes, identity conditions are preserved across admissible continuations, and admissible futures do not branch uncontrollably.

Histories admissible under $\mathbf{RSVP}_{\text{low}}$ therefore exhibit persistent structural invariants and laminar constraint propagation. These conditions correspond exactly to the modeling assumptions tacitly required by entity-centric ontologies.

F.3 Interpretation Map

We define an interpretation map

$$I : \mathbf{BFO} \to \mathbf{RSVP}_{\text{low}}$$

that assigns to each BFO model a corresponding RSVP regime.

Independent continuants are interpreted as stabilized regions of history whose scalar density exceeds the stability threshold and whose entropy remains bounded under admissible continuation. Occurrents are interpreted as coherent trajectories of nonzero vector flow through admissible histories. The continuantâĂŞoccurrent distinction is thus realized as a regime distinction rather than a primitive sortal division.

Participation relations are interpreted as stable couplings between scalar-dense regions and vector trajectories. Dependence relations correspond to constraints on admissible futures that prohibit continuation in the absence of the relevant stabilized structure.

F.4 Soundness of the Interpretation

[Soundness] For every model $\mathcal{M}$ of **BFO**, the interpretation $I(\mathcal{M})$ is a valid model of $\mathbf{RSVP}_{\text{low}}$.

Proof. Let $\mathcal{M}$ be a model of **BFO**. By the axioms of BFO, continuants persist across time, occurrents unfold in time, and participation preserves identity of continuants. These axioms imply that admissible futures of any history in $\mathcal{M}$ are constrained so as to preserve identity and participation relations.

Therefore entropy is bounded in the induced RSVP regime, and scalar density of continuants remains above threshold. Vector flow corresponding to occurrents is laminar and does not destabilize scalar regions. Hence $I(\mathcal{M})$ satisfies the defining conditions of $\mathbf{RSVP}_{\text{low}}$. □

F.5 Completeness up to Conservative Extension

[Conservative Embedding] Let φ be any sentence expressible in the language of **BFO**. Then $\mathbf{BFO} \models \varphi$ if and only if $\mathbf{RSVP}_{\text{low}} \models I(\varphi)$.

Proof. If $\mathbf{BFO} \models \varphi$, then φ holds in every BFO model. By soundness, every such model corresponds under I to an RSVP low-entropy regime in which $I(\varphi)$ holds. Conversely, if $I(\varphi)$ holds in every $\mathbf{RSVP}_{\text{low}}$ model, then in particular it holds in all regimes arising from BFO models. Since I preserves the interpretation of BFO predicates, φ holds in all BFO models. Hence the embedding is conservative. □

This theorem establishes that RSVP does not invalidate BFO within its domain of competence. Rather, it strictly generalizes it.

F.6 Failure Outside Low-Entropy Regimes

We now show that the embedding cannot be extended beyond low-entropy regimes.

[Non-Extendability] There exists no conservative embedding of **BFO** into RSVP regimes with unbounded entropy.

Proof. In regimes with unbounded entropy, admissible futures branch across mutually incompatible continuations. Identity conditions for continuants cannot be preserved across all admissible futures. Since BFO axioms require such preservation, no interpretation satisfying those axioms can exist in these regimes. Therefore no conservative embedding is possible. □

This result explains why BFO-style ontologies encounter systematic difficulty when applied to highly dynamic, versioned, or socio-technical domains. The difficulty is ontological rather than methodological.

F.7 Interpretive Consequences

The embedding theorems establish that BFO is a valid and rigorous ontology within a specific entropic regime. Its apparent rigidity reflects the stability of the domains for which it was designed. RSVP does not replace BFO; it situates it.

More generally, the result demonstrates that disagreements between static and dynamic ontologies are not disputes about realism versus anti-realism. They are disputes about regime assumptions concerning entropy, stabilization, and historical admissibility.

RSVP provides a formal language in which these assumptions can be stated, analyzed, and compared. In doing so, it offers a unifying foundation for ontology engineering that preserves the achievements of classical realism while extending its reach.

G A Worked Cognitive Example: Learning as Constraint Stabilization

This appendix develops a worked cognitive example illustrating how learning processes are represented within the RSVP ontology. The purpose is not to model neural implementation details, but to formalize learning as the progressive stabilization of admissible histories under constraint. The analysis applies equally to biological and artificial learning systems.

G.1 Learning Systems as Historical Processes

Let a learning system be characterized by a sequence of interaction events with an environment. Each interaction produces an irreversible update to the systemâĂŹs internal state. Let e_i denote the i-th update event, and let the learning history at time t be

$$h_t = (e_1 \prec e_2 \prec \cdots \prec e_t).$$

Admissibility constraints encode viability conditions such as coherence of internal representation, bounded resource consumption, and compatibility with environmental feedback. A learning history is admissible if it satisfies these constraints and admits further extension without collapse.

G.2 Hypothesis Spaces and Entropic Structure

Let $\mathcal{H}_t$ denote the hypothesis space compatible with the learning systemâĂŹs internal state at time t. Each hypothesis corresponds to a distinct way the system may interpret or act upon future inputs. The admissible futures of the learning history correspond to trajectories through $\mathcal{H}_t$ that remain compatible with feedback.

The entropy of the learning state at time t is defined as

$$S(h_t) = \log |\mathcal{H}_t|.$$

Early in learning, entropy is high: many hypotheses remain admissible. As learning progresses, feedback eliminates incompatible hypotheses, reducing entropy. This reduction is irreversible, since eliminated hypotheses cannot be reinstated without violating historical consistency.

G.3 Scalar Density and Learned Representations

Let R denote a representational invariant, such as a learned category, policy, or predictive structure. Scalar density $\Phi(R, h_t)$ measures the persistence of R across admissible futures. Formally, $\Phi(R, h_t)$ is high if all hypotheses in $\mathcal{H}_t$ realize R up to equivalence.

A representation becomes meaningful precisely when its scalar density exceeds a threshold. Before this point, the system does not yet possess the representation in an ontologically robust sense; it merely entertains it among many alternatives.

G.4 Vector Flow and Learning Direction

Learning is directional. Feedback does not merely restrict hypothesis space but biases it. This bias is captured by the vector field $\vec{v}$, which assigns to each learning event a directional influence on the evolution of $\mathcal{H}_t$.

Gradient-based learning corresponds to smooth vector flow that steadily reduces entropy. Abrupt regime changes, such as catastrophic forgetting or phase transitions in representation, correspond to sharp changes in vector orientation and magnitude.

G.5 Stability and Generalization

Generalization corresponds to stability under admissible continuation. A learned structure generalizes if it persists across future interactions not yet encountered. In RSVP terms, generalization requires both bounded entropy and high scalar density.

[Generalization as Entropy Suppression] A learned representation generalizes if and only if the entropy of admissible learning futures is bounded below a critical threshold while scalar density remains high.

Proof. If entropy is unbounded, admissible futures include incompatible hypotheses, and the representation fails to persist. Conversely, if entropy is bounded and scalar density remains high, all admissible futures preserve the representation, yielding generalization. □

G.6 Overfitting and Underspecification

Overfitting corresponds to excessive entropy suppression relative to the true structure of the environment. The learning system collapses admissible futures too aggressively, producing a brittle scalar regime. Underspecification corresponds to insufficient entropy reduction, leaving multiple incompatible futures admissible.

Both phenomena are naturally expressed in RSVP terms as mismanagement of entropy rather than as failures of representation alone.

G.7 Identity and Agency

A learning agent acquires identity when its policy or representational structure becomes invariant across admissible futures. Agency is not primitive; it emerges when vector flow becomes coherent and scalar density stabilizes sufficiently to support counterfactual robustness.

This account explains why agency degrades under distributional shift or nonstationary environments. Entropy increases, scalar density decreases, and identity dissolves.

G.8 Artificial Learning Systems

The analysis applies directly to artificial learning systems. Training corresponds to historical constraint accumulation. Model parameters encode scalar density. Optimization dynamics encode vector flow. Dataset diversity and nonstationarity contribute to entropy.

This perspective clarifies why scaling alone does not guarantee intelligence. Without mechanisms that regulate admissible futures, entropy may remain high even in large systems, preventing stable identity or agency from emerging.

G.9 Interpretation

The cognitive example demonstrates that RSVP provides a principled ontology of learning that subsumes statistical, dynamical, and symbolic perspectives. Learning is not merely parameter adjustment or belief update; it is the irreversible shaping of admissible futures.

By grounding cognition in constraint stabilization rather than representational substance, RSVP offers a unified account of learning, generalization, and agency that applies across biological and artificial systems.

H Indivisibility, Unistochastic Dynamics, and Emergent Quantum Structure

This appendix develops a formal connection between the RSVP ontology and indivisible stochastic dynamics, showing how quantum-like structure can emerge without positing wave functions or Hilbert space as ontological primitives. The analysis builds on the notion that irreversibility and history dependence, when combined with probabilistic admissibility, force a departure from classical factorization.

H.1 Indivisible Histories

A history $h \in \mathcal{H}$ is said to be temporally divisible if it admits a factorization into conditionally independent subhistories. Formally, h is divisible if there exists a nontrivial prefix $h_1 \prec h$ such that admissible continuation probabilities satisfy

$$P(h \mid h_1) = \prod_i P(h_i \mid h_1),$$

where the h_i are independent extensions. A history is indivisible when no such factorization exists.

Indivisibility arises naturally in RSVP when admissibility constraints couple future events nonlocally across history. Entropy production, once conditioned on past constraint accumulation, introduces correlations that cannot be decomposed into independent steps.

H.2 Stochastic Admissibility

Let $P(h' \mid h)$ denote the probability that a given admissible extension h' occurs, conditioned on the prefix h. These probabilities are not fundamental; they summarize ignorance about which admissible continuation will be realized.

In divisible regimes, these probabilities factor through intermediate prefixes. In indivisible regimes, they do not. The law of total probability remains valid, but temporal factorization fails.

H.3 Unistochastic Transition Structure

Consider a finite entropy-bounded regime in which admissible futures form a finite set $\mathrm{Fut}(h)$. Let T be the matrix of transition probabilities between coarse-grained states induced by admissible history extensions. In general, T need not be stochastic with respect to any underlying deterministic process.

[Unistochastic Representation] If admissible histories are indivisible but entropy-bounded, then the transition matrix T admits a unistochastic representation.

Proof. Indivisibility implies that probabilities cannot be represented as convex combinations of deterministic trajectories. However, entropy bounds ensure finite-dimensionality of admissible futures. By construction, T satisfies the constraints of doubly stochastic normalization. By the BirkhoffâĂŞvon Neumann theorem and its unistochastic refinement, T may be represented as the squared moduli of a unitary matrix. The phases encode historical interference effects arising from non-factorizable admissibility. □

This result shows that unitary structure emerges as a representational necessity when histories are indivisible, not as a postulate about physical reality.

H.4 Interference as Historical Coupling

Interference phenomena arise when distinct admissible histories contribute non-additively to future probabilities. In RSVP terms, this occurs when scalar density and entropy jointly constrain admissibility so that alternative paths cannot be treated independently.

The complex phases in the unistochastic representation encode the orientation of vector flow across history space. Constructive and destructive interference correspond to alignment or opposition of these flows.

H.5 Measurement as Entropy Collapse

Measurement corresponds to a reduction of admissible futures induced by coupling to a low-entropy apparatus. The apparent collapse of probabilistic structure is an update of admissibility constraints, not a physical discontinuity.

[Measurement Update] Measurement reduces entropy by restricting admissible histories while preserving indivisibility of the realized trajectory.

Proof. Coupling to a measurement apparatus imposes additional constraints that eliminate large subsets of admissible futures. The realized history remains indivisible, since the constraints act globally on admissibility rather than locally on events. □

H.6 Classical Limit

The classical limit corresponds to regimes in which entropy is low and histories become approximately divisible. In such regimes, unistochastic matrices approach stochastic ones, and interference terms vanish. Scalar density dominates vector flow, yielding stable identity and classical behavior.

H.7 Interpretation

This appendix demonstrates that quantum-like formal structure arises naturally within RSVP from two conditions alone: irreversibility of history and bounded but indivisible admissibility. No appeal to microscopic ontology or wave function realism is required.

RSVP thus provides a unified explanatory framework in which classical mechanics, statistical mechanics, and quantum phenomena appear as regime-dependent manifestations of the same underlying historical ontology.

I References

References

[1] B. Smith, W. Ceusters, B. Klagges, J. KÃűhler, A. Kumar, J. Lomax, C. Mungall, F. Neuhaus, A. Rector, and C. Rosse. Relations in biomedical ontologies. *Genome Biology*, 6(5):R46, 2005.

[2] R. Arp, B. Smith, and A. D. Spear. *Building Ontologies with Basic Formal Ontology.* MIT Press, Cambridge, MA, 2015.

[3] N. Guarino. Formal ontology and information systems. In *Proceedings of FOIS 1998*, pages 3–15. IOS Press, 1998.

[4] C. Masolo, S. Borgo, A. Gangemi, N. Guarino, and A. Oltramari. Ontology library. *WonderWeb Deliverable D18*, 2003. (DOLCE foundational ontology.)

[5] P. Grenon and B. Smith. SNAP and SPAN: Towards dynamic spatial ontology. *Spatial Cognition and Computation*, 4(1):69–104, 2004.

[6] J. Beverley and B. Smith. Debates on artificial intelligence and ontology engineering, Part 2. Public debate transcript, 2025.

[7] J. Barandes. Indivisible stochastic processes and quantum mechanics. *Foundations of Physics*, 52:1–31, 2022.

[8] E. T. Jaynes. *Probability Theory: The Logic of Science*. Cambridge University Press, Cambridge, 2003.

[9] K. Friston. The free-energy principle: a unified brain theory? *Nature Reviews Neuroscience*, 11(2):127–138, 2010.

[10] R. Landauer. Irreversibility and heat generation in the computing process. *IBM Journal of Research and Development*, 5(3):183–191, 1961.

[11] C. E. Shannon. A mathematical theory of communication. *Bell System Technical Journal*, 27:379–423, 623–656, 1948.

[12] L. Floridi. *The Philosophy of Information*. Oxford University Press, Oxford, 2011.

[13] E. Hutchins. *Cognition in the Wild*. MIT Press, Cambridge, MA, 1995.

[14] R. Rosen. *Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life*. Columbia University Press, New York, 1991.

[15] A. N. Whitehead. *Process and Reality*. Free Press, New York, 1929.

[16] H. A. Simon. *The Sciences of the Artificial*. MIT Press, Cambridge, MA, 3rd edition, 1996.

[17] J. Propp. Exploding dots and their applications. *The Mathematical Intelligencer*, 36(4), 2014.