Irreversible Histories as Ontological Primitives:
A Constraint-First Foundation for Dynamic Ontologies

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December 26, 2025

Abstract

This paper argues that irreversible history, rather than entityhood, must be treated as a top-level ontological primitive in any system intended to model dynamic, evolving domains. Contemporary ontology engineering frameworks, particularly those grounded in Description Logic and exemplified by the Basic Formal Ontology (BFO), presuppose identity preservation and monotonic accumulation of facts. These assumptions render them systematically incapable of representing irreversible commitment, entropy-driven divergence, and historical dependence. We propose a constraint-first alternative in which entities emerge as stabilized invariants within admissible histories, rather than serving as foundational primitives. The paper analyzes the formal limits of OWL-based reasoning, demonstrates how ontology drift arises as an entropic phenomenon rather than an engineering defect, and outlines a history-based foundation capable of subsuming classical ontologies as low-entropy special cases.

1 Introduction

Ontology engineering has traditionally prioritized entities over processes, treating objects as primary and histories as derivative. This orientation has proven effective in static or slowly evolving domains, but it fails systematically when applied to systems characterized by irreversibility, learning, agency, or semantic drift. This paper argues that these failures are not accidental, nor are they merely limitations of tooling. They arise from a deeper metaphysical commitment to state-based identity that is incompatible with dynamic reality.

2 The Entity-Centric Assumption in Formal Ontologies

We examine the implicit assumptions shared by dominant ontology frameworks, focusing on the treatment of identity, persistence, and change. Particular attention is paid to the continuant-occurrent distinction in BFO and its reliance on identity-preserving mappings across time.

3 Irreversibility and the Failure of State-Based Identity

This section formalizes irreversibility as an ontological constraint rather than an epistemic inconvenience. We show that once history is treated as constitutive rather than auxiliary, identity becomes

path-dependent and non-reversible, undermining entity-first modeling strategies.

4   Limits of Description Logic and OWL

We demonstrate that Description Logic is structurally incapable of representing irreversible exclusion, refusal, and entropy-bounded futures. The argument is not that OWL lacks expressivity in practice, but that its monotonic semantics prohibit the representation of ontological inadmissibility.

5   A Constraint-First Ontological Foundation

We introduce a history-first ontology in which admissible futures, rather than entities, form the primary semantic domain. Scalar stability, vector constraint propagation, and entropy over futures are introduced as abstract structural primitives suitable for cross-domain application.

6   Ontology Drift as an Entropic Phenomenon

Using a worked example of ontology versioning, we show that mapping failures over time arise from entropy accumulation rather than inconsistency or poor design. Identity divergence is shown to be inevitable once histories branch irreversibly.

7   Relation to Existing Ontologies

We demonstrate how entity-centric ontologies such as BFO can be embedded as low-entropy subtheories within a history-first framework. Their empirical success is explained without granting them foundational status.

8   Implications for AI, Learning Systems, and Agency

The framework is extended to artificial systems whose identities evolve through training and interaction. Intelligence is characterized as the maintenance of low-entropy histories under constraint rather than the possession of static representations.

Ontology engineering must shift from describing what exists to constraining what can continue to exist. Treating irreversible histories as ontological primitives provides a unified explanation for the successes and failures of existing frameworks while opening a principled path toward representing dynamic, agentive systems.

9   Limits of Description Logic and OWL

Description Logic (DL), and by extension OWL-based ontology engineering, is founded on a set of semantic commitments that privilege monotonicity, open-world reasoning, and state-based identity. These commitments have proven extremely effective for classification, subsumption reasoning,

and interoperability in domains where entities are assumed to persist and where change is either negligible or externally managed. However, when applied to dynamic systemssuch as evolving scientific theories, learning agents, biological lineages, or socio-technical infrastructuresthese same commitments become structural liabilities.

The core limitation is not a lack of expressive power in the syntactic sense, but an incompatibility between DL semantics and irreversible historical dependence. OWL reasoners operate over interpretations that assign truth values to assertions in a model-theoretic space where knowledge can be extended but never invalidated. Once an assertion is entailed, it remains entailed under any admissible extension of the ontology. This monotonicity precludes the representation of exclusion as a first-class ontological operation. In particular, OWL cannot express that a future state of the ontology is inadmissible due to prior commitments, only that it is currently unasserted.

This becomes decisive when modeling identity over time. In OWL, identity is preserved unless explicitly contradicted, yet contradiction itself has no constructive role. The logic has no native mechanism for expressing that an entity has ceased to exist as a result of historical commitments, or that a previously valid classification has become ontologically impossible. Retraction, when supported at all, is an external engineering operation rather than an internal semantic event.

As a result, OWL ontologies systematically conflate absence with impossibility. The failure to assert a relation is indistinguishable from a principled refusal of that relation. This distinction is not merely philosophical. In systems where agency, policy enforcement, or irreversible decisions matter, the inability to encode inadmissibility collapses crucial semantic structure. A system may be forced to treat prohibited actions, obsolete identities, or invalid mappings as merely unknown rather than structurally ruled out.

Attempts to address these limitations through non-monotonic extensions, rule layers, or external versioning systems only defer the problem. They treat irreversibility as a meta-level concern rather than as an ontological primitive. The consequence is an ever-growing gap between the formal ontology and the system it is intended to model, particularly as that system evolves over time.

10   A Constraint-First Ontological Foundation

To overcome these limitations, we propose a constraint-first ontological foundation in which irreversible history, rather than entityhood, serves as the primary semantic primitive. In this framework, the basic object of ontology is not an entity at a time, but a history constrained by admissibility conditions. Ontological meaning is defined not by what exists in a snapshot, but by which futures remain possible given what has already occurred.

Formally, we begin with a space of admissible histories, each history being a finite, prefix-closed sequence of events. An event is defined not merely as a change in state, but as an irreversible commitment that restricts future extensions of the history. The ontology is thus a theory of which histories are admissible, rather than a catalog of which entities exist.

Entities, in this view, are secondary constructs. They emerge as stabilized invariants across families of histories that share sufficient structural similarity. Identity is therefore not primitive but derived. An entity persists not because it is assumed to do so, but because the constraints governing

admissible histories permit its continued re-identification under entropy-bounded variation.

Three abstract structural components suffice to describe this foundation across domains. Scalar stability captures the degree to which a structure resists dissolution across histories. Vector constraint propagation represents directed influence, causation, or control that shapes which future events are admissible. Entropy measures the degeneracy of admissible futures compatible with a given history. Together, these primitives define a semantic field over histories rather than a taxonomy over entities.

Crucially, this framework admits exclusion as a first-class ontological operation. A history may render entire classes of future events inadmissible, not merely unlikely or unasserted. This allows refusal, commitment, and obligation to be modeled as structural features of the ontology itself, rather than as annotations layered atop an entity-centric core.

11   Ontology Drift as an Entropic Phenomenon

One of the most persistent challenges in ontology engineering is ontology drift: the gradual failure of mappings between ontologies, versions, or domains as systems evolve. Drift is typically treated as an engineering problem arising from inconsistent updates, insufficient governance, or inadequate alignment practices. From a history-first perspective, this diagnosis is incomplete.

Ontology drift is better understood as an entropic phenomenon. As histories branch and constraints accumulate, the space of admissible futures diverges. Mappings that were valid under earlier constraints may become inadmissible under later ones, not because of error, but because the systems they describe have undergone irreversible differentiation.

Consider an ontology describing biological cell types across developmental time. Early in development, classifications may be coarse and broadly compatible. As differentiation proceeds, commitments are made that rule out entire classes of futures. Attempting to preserve earlier identity mappings across these commitments leads to semantic incoherence. The failure is not in the mapping, but in the assumption that identity can be preserved without accounting for history-dependent exclusion.

The same pattern appears in machine learning systems whose internal representations evolve through training. A model before and after fine-tuning cannot be assumed to share identity in any strong ontological sense, even if their architectures are identical. The training process constitutes a sequence of irreversible commitments that reshape the models admissible behaviors. Treating such systems as instances of a single enduring entity obscures the very dynamics that define their operation.

By modeling ontology mappings as relations between histories rather than between entities, drift becomes intelligible and predictable. Mappings fail when entropy exceeds the tolerance of the invariant structure being tracked. This reframes ontology maintenance as the management of entropy and constraint, rather than as a purely syntactic alignment task.

12 Embedding Entity-Centric Ontologies as Low-Entropy Subtheories

The proposed event-historical ontology does not reject existing top-level ontologies such as the Basic Formal Ontology (BFO); rather, it re-situates them as special cases within a broader semantic landscape. Entity-centric ontologies can be understood as low-entropy subtheories of a history-first foundationdomains in which the space of admissible futures is sufficiently constrained that identity appears stable, persistence can be idealized, and irreversible differentiation is negligible over the relevant timescale.

BFOs central distinction between continuants and occurrents exemplifies this regime. Continuants are treated as entities that persist through time while maintaining identity, whereas occurrents are processes in which these entities participate. From a history-first perspective, this distinction corresponds to a modeling choice in which certain historical commitments are collapsed into equivalence classes that preserve identity across a bounded range of variation. Persistence is not a primitive fact, but a consequence of aggressive abstraction over admissible histories.

This abstraction is valid and useful in domains such as anatomy, materials science, and stable engineering artifacts, where entropy is low and structural differentiation proceeds slowly relative to observational needs. In such cases, treating entities as primary is not ontologically false but pragmatically efficient. The failure arises when this modeling stance is implicitly universalized and applied to domains characterized by rapid differentiation, learning, or adaptive control.

Within the RSVP framework, BFO-style ontologies arise through a quotient operation over histories that identifies all variations below a given entropy threshold. The resulting ontology is sharply defined, monotonic, and well-suited to OWL-style reasoning. However, this quotient is lossy. Once applied, it eliminates the semantic resources needed to reason about irreversible commitments, refusal, or historical exclusion. As such, BFO is best understood not as a foundational ontology, but as an interface ontology optimized for low-entropy regimes.

This reframing resolves a long-standing tension in ontology engineering. It explains both the success of entity-centric ontologies in stable domains and their repeated breakdown when applied to dynamic systems. The issue is not that such ontologies are incomplete, but that they are overextended beyond the regimes in which their abstractions remain faithful.

13 Worked Example: Ontology Versioning and Identity Drift

To illustrate the practical implications of a history-first ontology, consider the problem of ontology versioning in a scientific domain undergoing rapid conceptual change. Traditional approaches treat successive ontology versions as revisions of a single enduring entity, linked by mappings that attempt to preserve class identity wherever possible. When mappings fail, the failure is attributed to poor alignment or insufficient documentation.

In an event-historical framework, each ontology version is instead treated as a distinct stabilized history, produced by a sequence of irreversible commitments. The introduction of a new class, the redefinition of an existing one, or the exclusion of a previously valid relation are all modeled as

events that prune the space of admissible futures. Identity across versions is therefore not assumed but must be justified by demonstrating that sufficient invariant structure survives the accumulated constraints.

Suppose an ontology initially defines a class *RegulatoryProtein* based on functional criteria. A later revision incorporates structural constraints that exclude several proteins previously classified under this term. In a state-based ontology, this produces a conflict: either identity is preserved at the cost of incoherence, or identity is broken without formal justification. In the history-first model, the later revision is recognized as having made commitments that render certain past classifications inadmissible. The original class does not persist unchanged; it undergoes ontological differentiation.

Mappings between versions are thus relations between histories rather than between entities. A mapping is valid only if the entropy introduced by the revision remains within the tolerance bounds of the invariant being tracked. When this bound is exceeded, identity collapse is not an error but an expected outcome. Ontology drift is thereby reinterpreted as a measurable divergence in admissible futures rather than as a failure of alignment practice.

This approach provides clear guidance for ontology engineering. Rather than attempting to force identity preservation, engineers can explicitly model points of irreversible divergence and decide whether to introduce collapse operations that preserve continuity or to acknowledge the emergence of genuinely new ontological structures.

14 Implications for Artificial Agents and Alignment

The relevance of irreversible histories extends beyond ontology engineering into the design and analysis of artificial agents. Contemporary AI systems, particularly those based on autoregressive or reinforcement learning paradigms, are typically modeled as state-based optimizers. Their internal updates are treated as reversible adjustments to parameters rather than as ontologically binding commitments.

From a history-first perspective, this modeling choice explains a fundamental limitation of such systems: their inability to sustain identity, obligation, or responsibility over time. An agent that can always revise its internal state without structural consequence cannot meaningfully refuse an action, bear the cost of a past decision, or bind itself to a future course. Its apparent behavior may be coherent, but its ontology remains shallow.

An artificial agent exhibits agency in the strong sense only if it can make irreversible commitments that constrain its future behavior. Training, alignment, and policy enforcement must therefore be understood not merely as optimization processes, but as entropy-reduction operations that stabilize identity across histories. An aligned agent is not one whose instantaneous outputs satisfy constraints, but one whose admissible futures have been structurally shaped such that certain actions are no longer possible.

This perspective has direct implications for alignment research. Safety mechanisms implemented as external filters or reward modifiers remain fragile because they operate at the level of state evaluation rather than historical exclusion. A history-first ontology suggests that alignment must be implemented as refusal at the level of admissible action spaces, embedded into the agents identity

rather than imposed episodically.

By grounding agency in irreversible history, the RSVP framework provides a principled way to distinguish between systems that merely simulate deliberation and those that genuinely inhabit a world shaped by their past. This distinction is essential for any ontology intended to support reasoning about responsibility, trust, or long-term interaction with artificial systems.

15 Conclusion: Ontology as the Study of Admissible Futures

This paper has argued that irreversible histories, rather than static entities, should serve as the primitive objects of ontology engineering. By re-centering ontology on admissible histories under constraint, the RSVP framework resolves persistent difficulties associated with irreversibility, identity drift, and dynamic system behavior. It explains why entity-centric ontologies succeed in low-entropy domains while failing in regimes characterized by learning, adaptation, or social interaction.

The central contribution is not the rejection of existing ontologies, but their contextualization. Classical frameworks such as BFO are recovered as valid, low-entropy projections of a more general history-first semantics. OWL and Description Logic remain indispensable tools, but their limits are rendered intelligible rather than anomalous.

More broadly, this work reframes ontology as the study of possible and impossible futures rather than as a taxonomy of what exists. Meaning, identity, and agency emerge not from static classification, but from the irreversible commitments that shape what can no longer be otherwise. In dynamic domainsfrom biology to artificial intelligence to social systemsthis shift is not optional. It is a prerequisite for ontologies that remain faithful to the systems they seek to describe.

16 Limits of Description Logic and OWL Under Irreversibility

While the history-first ontology proposed here is compatible with classical knowledge-representation tools, it also exposes principled limits of Description Logic (DL) and the Web Ontology Language (OWL). These limits are not implementation deficiencies but arise from deep semantic commitments embedded in the logic itself.

OWL ontologies are founded on a model-theoretic semantics in which truth is evaluated relative to interpretations that are static, monotonic, and extensional. Once a statement is entailed, it remains entailed under ontology extension. This monotonicity property is essential for decidability and tractable reasoning, but it implicitly assumes that ontological commitment is reversible only by retraction at the meta-level. OWL lacks any internal notion of historical exclusion, refusal, or commitment that permanently alters the space of admissible interpretations.

In contrast, an event-historical ontology treats commitment as an internal operation that changes what can be said in the future. A refusal is not a negated assertion but the elimination of an interpretation altogether. Such operations cannot be faithfully represented in OWL without reifying histories as individuals and simulating temporal constraint through ad hoc constructs. Doing so preserves syntactic expressivity but breaks semantic faithfulness, as the logic

continues to treat all admissible interpretations as contemporaneously possible.

This mismatch explains recurring pathologies in applied ontology engineering. Attempts to represent policy, obligation, governance, or identity over time typically resort to annotation properties, temporal indices, or layered ontologies that simulate evolution while preserving a fundamentally static core. These techniques work locally but fail compositionally. They cannot express that a future state is impossible because of a past commitment, only that it is currently disallowed under a contingent rule set.

From the RSVP perspective, OWL corresponds to a collapsed, low-entropy projection of a richer semantic space. It is well-suited for reasoning within a fixed regime of admissible futures, but structurally incapable of representing transitions between regimes. This limitation is intrinsic, not accidental, and clarifies why ontology engineers repeatedly encounter irreducible complexity when modeling dynamic domains within purely description-logical frameworks.

17   A Hybrid Architecture: History Kernels with Logical Views

Rather than proposing the replacement of OWL or DL-based systems, this work motivates a stratified ontology architecture that separates irreversible commitment from logical inference. Such an architecture mirrors the distinction already implicit in successful computational systems between authoritative state and derived views.

At the base of the architecture lies a history kernel, responsible for maintaining the authoritative event history. This kernel enforces authorization, refusal, and collapse operations, ensuring that all extensions of the ontology respect irreversible commitments. The kernel is not queried directly by users or reasoning engines; it functions as the causal substrate of the system.

Above this kernel sits a logical view layer, generated by projecting the current admissible histories into a static ontology suitable for OWL reasoning. This projection necessarily involves collapse: distinctions that matter for future admissibility may be suppressed in order to support efficient classification and entailment. Crucially, this collapse is explicit and one-way. Logical entailments never feed back into the kernel as commitments.

In this architecture, OWL ontologies regain a clear and principled role. They are not global truth-makers, but snapshots of a historically constrained semantic landscape. Reasoners operate over these snapshots to answer questions about classification, subsumption, and consistency within the current regime. When regime changes occurthrough new commitments or refusalsthe view is regenerated rather than incrementally patched.

This separation resolves several long-standing tensions in ontology engineering. It allows logical inference to remain monotonic and decidable while enabling the underlying ontology to evolve irreversibly. It also prevents category errors in which normative or procedural constraints are mistakenly encoded as descriptive facts. Ethics, policy, and governance remain grounded in commitment at the kernel level, while logic remains a tool for navigation within the resulting space.

18   Formal Identity Conditions Under Entropy Bounds

A central challenge for any ontology is the specification of identity conditions. In entity-centric frameworks, identity is typically treated as primitive or defined via necessary and sufficient conditions. This approach breaks down in dynamic domains, where the properties that define an entity may change irreversibly.

The RSVP framework replaces static identity with entropy-bounded identity. Two histories are said to represent the same entity if the divergence between their admissible futures remains below a specified entropy threshold. Identity is thus neither absolute nor subjective, but parameterized by tolerance to future differentiation.

Formally, let H_1 and H_2 be two event histories, and let $\mathcal{F}(H)$ denote the space of admissible futures extending H. Define an entropy measure $S(\mathcal{F}(H))$ over this space. Identity equivalence is then defined relative to a bound ϵ such that

$$|S(\mathcal{F}(H_1)) - S(\mathcal{F}(H_2))| \leq \epsilon.$$

When this condition holds, the histories may be collapsed into a single identity for the purposes of reasoning at that resolution. When it fails, identity differentiation is ontologically mandatory.

This formalization has immediate practical consequences. In ontology versioning, it provides a principled criterion for when a class revision preserves identity versus when it introduces a new ontological kind. In agent modeling, it distinguishes gradual learning from identity-altering commitment. In biological ontology, it clarifies when developmental change preserves organismal identity and when it produces differentiation.

By making identity explicitly dependent on entropy bounds, the framework avoids both rigid essentialism and unrestricted relativism. Identity becomes a controlled abstraction, justified by constraints on future divergence rather than by fiat.

19   Scope and Future Directions

The ontology of irreversible histories outlined here is intentionally ambitious. It seeks not merely to patch deficiencies in existing frameworks, but to provide a unifying semantic foundation for systems characterized by change, commitment, and constraint. While the present work has focused on ontology engineering, the implications extend naturally to database systems, legal reasoning, scientific modeling, and artificial intelligence.

Future work may pursue several directions. One is the formalization of kernel-level authorization languages capable of expressing rich policy constraints while remaining computationally tractable. Another is the development of tooling that supports bidirectional navigation between history kernels and logical views, enabling ontology engineers to reason about both structure and evolution without conflating them.

Perhaps most importantly, this framework invites a re-examination of what it means for an ontology to be correct. Correctness is no longer a matter of correspondence to a static world, but of fidelity to the irreversible structure of becoming. An ontology succeeds when it preserves

the constraints that make future reasoning coherent, even as the space of possibilities continues to evolve.

In this sense, ontology engineering becomes inseparable from responsibility. To define what exists is to rule out what cannot, and to do so irreversibly. A history-first ontology does not merely describe a world; it participates in its construction.

20 Why Temporal Ontologies Are Insufficient

A natural objection to the event-historical framework is that existing temporal ontologies already provide tools for representing change over time. Standards such as OWL-Time, perdurantist extensions of BFO, and 4D-fluent approaches all attempt to reconcile identity with temporal variation. However, these frameworks ultimately preserve a state-based metaphysics and therefore fail to capture irreversibility as an ontological primitive.

Temporal ontologies typically represent time as an additional index or dimension along which properties vary. An entity is modeled as a sequence of time-slices or as a continuant that bears different properties at different temporal coordinates. While this allows one to state that a property held at time t_1 and not at t_2, it does not express that certain futures have been rendered inadmissible by past events. All temporal slices are treated symmetrically as possible states of affairs within the same model.

In contrast, the event-historical framework treats time as asymmetric and constructive. Past events are not merely earlier states but commitments that constrain the future. A refusal at time t does not simply mean that an action is false at later times; it means that no admissible continuation exists in which that action occurs. This distinction cannot be expressed in temporal description logics without collapsing into meta-level reasoning about models rather than object-level ontology.

The insufficiency of temporal ontologies becomes especially apparent in domains involving governance, policy, or institutional rules. For example, a regulation that permanently prohibits a class of actions cannot be faithfully represented as a time-indexed predicate without losing its binding force. The temporal encoding can express that the action is disallowed at all future times, but it cannot represent the structural fact that the prohibition itself is an irreversible event whose revocation would require a distinct counter-event. In RSVP terms, temporal ontologies describe trajectories within a fixed option-space, whereas event-historical ontologies describe transformations of the option-space itself.

21 Worked Example: Ontology Version Drift and Identity Failure

To illustrate the practical consequences of a history-first ontology, consider the problem of ontology version drift. In large-scale knowledge systems, ontologies evolve over time as definitions are refined, classes are split or merged, and constraints are added or removed. Classical ontology engineering treats these changes as revisions to a theory, often assuming that backward compatibility or mapping alignment can be achieved through correspondence axioms.

From an event-historical perspective, ontology evolution is a sequence of irreversible commit-

ments. Each release is not merely a new description but a constraint on future interpretations. Consider an ontology O_0 containing a class `Person`. At time t_1, a revision introduces a commitment distinguishing `BiologicalPerson` from `LegalPerson`. This is not merely an enrichment of vocabulary; it permanently eliminates futures in which the undifferentiated `Person` class remains semantically adequate.

In a state-based framework, one attempts to map instances of `Person` in O_0 to instances of the new subclasses using alignment rules. However, such mappings frequently fail in practice because the original data lacks the discriminative information required by the new ontology. This failure is often attributed to data quality or modeling oversight.

The event-historical framework provides a deeper diagnosis. The entropy of admissible futures has increased asymmetrically. The original ontology permitted a broader range of future refinements, whereas the revised ontology commits to a narrower interpretive regime. The failure of mapping is not accidental; it is a consequence of an irreversible ontological commitment that invalidates certain histories as continuations of the same identity.

Formally, let H_0 denote the history up to ontology O_0, and $H_1 = H_0 \cdot e_{\text{split}}$ denote the history including the class-splitting event. The space of admissible futures $\mathcal{F}(H_1)$ is not a refinement of $\mathcal{F}(H_0)$ but a restriction. Attempting to map backward from H_1 to H_0 is therefore ill-typed unless a collapse operation is explicitly authorized, identifying distinctions that are now known to be semantically relevant.

This analysis explains why ontology alignment across versions often requires manual intervention, normative judgment, or institutional authority. These are not engineering failures but signals that identity has crossed an entropy threshold beyond which automatic reconciliation is no longer ontologically sound.

22 Agent Identity and Commitment in Knowledge Systems

The same formalism applies to agent identity, whether biological, institutional, or artificial. Classical ontologies typically model agents as continuants with stable identifiers. Changes in beliefs, goals, or capabilities are treated as property updates. This approach obscures the distinction between learning and identity-altering commitment.

Within the event-historical framework, an agent is defined by its history of commitments. Learning corresponds to changes in texture within a fixed kernel of admissible futures, whereas commitment corresponds to events that alter the kernel itself. For example, an agent that adopts a non-revocable policy constraintsuch as a constitutional prohibition or a hard safety boundaryundergoes an identity transition.

This distinction is critical for modeling artificial agents and AI systems. A model that updates weights through training but remains free to violate any prior behavior lacks commitment in the ontological sense. By contrast, an agent that records refusals as irreversible constraints acquires a form of identity that persists across future interactions.

Ontology engineering frameworks that fail to distinguish these cases risk conflating adaptive behavior with accountable agency. The RSVP model provides formal criteria for when an agent

remains the same entity under change and when it becomes a different one. Identity persistence is not guaranteed by continuity of structure or function alone, but by bounded divergence in admissible futures.

23 Implications for OWL-Based Tooling and Standards

The analysis presented here does not render OWL obsolete, but it does clarify its proper scope. OWL excels at reasoning within stabilized, low-entropy domains where admissible futures are effectively fixed. It is therefore well-suited for anatomical ontologies, taxonomies of material artifacts, and other domains characterized by slow or negligible regime change.

However, when applied to domains involving governance, policy, cognition, or evolving technical systems, OWL must be embedded within a larger semantic architecture. In such settings, OWL ontologies function as views over an event-historical substrate rather than as authoritative representations of reality.

This perspective suggests concrete design principles for future ontology engineering platforms. Reasoners should operate over snapshots generated by authorized collapse operations, and ontology editors should make regime-changing commitments explicit rather than implicit. Versioning systems should track entropy changes and signal when identity-preserving mappings are no longer justified.

Most importantly, ontology engineers should recognize that some disagreements cannot be resolved through better axiomatization because they concern incompatible commitments about admissible futures. In such cases, negotiation, authority, or explicit refusal is ontologically prior to logical reconciliation.

24 Conclusion: Ontology as the Science of Becoming

This work has argued that irreversible histories, rather than static entities, constitute the appropriate primitives for ontology engineering in dynamic domains. By grounding ontology in constraint, entropy, and commitment, the RSVP framework provides a unified account of identity, agency, and meaning across physical, biological, cognitive, and computational systems.

The central shift is conceptual rather than technical. Ontology is no longer the study of what exists, but of what can continue to exist given the commitments already made. Entities emerge as stabilized patterns within histories, and meaning arises from the irreversible pruning of futures.

Such a framework does not simplify ontology engineering, but it renders its difficulties intelligible. Mapping failures, alignment disputes, and semantic drift are not anomalies to be engineered away; they are manifestations of genuine ontological change. Recognizing this allows ontology engineers to move beyond brittle representational fixes toward architectures that respect the asymmetry of time and the cost of commitment.

In embracing irreversible history as ontological ground, we align ontology engineering with the structure of the world it seeks to describe: a world that does not merely change, but becomes.

25 Formal Limits of Description Logic for Irreversible Histories

The preceding sections motivate an event-historical ontology at a conceptual level. This section establishes a more formal claim: that standard description logics, including those underlying OWL 2 DL, are structurally incapable of representing irreversible commitments without externalizing essential semantics to the meta-level.

OWL semantics are model-theoretic and monotonic. Given an ontology $\mathcal{O}$, adding axioms can restrict the class of admissible interpretations, but no axiom can express that a particular interpretation was once admissible and has now been rendered inadmissible by a historical event. All admissibility is evaluated synchronically, relative to the completed axiom set. This collapses the distinction between *never possible* and *no longer possible*, which is precisely the distinction that event-historical ontologies require.

Formally, let $\mathcal{I}$ range over interpretations and let $\mathcal{O}_t$ denote an ontology at time t. In OWL, entailment is defined as

$$\mathcal{O}_t \models \varphi \quad \text{iff} \quad \forall \mathcal{I} \in \text{Mod}(\mathcal{O}_t),\ \mathcal{I} \models \varphi.$$

There is no representation of the set difference $\text{Mod}(\mathcal{O}_{t-1}) \setminus \text{Mod}(\mathcal{O}_t)$ as a first-class object. Yet it is exactly this difference that corresponds to an irreversible ontological commitment.

Attempting to encode irreversibility using time-indexed predicates merely pushes the problem upward. One can state that a property holds at all times $t \geq t_0$, but this still quantifies over a single, static model in which all times coexist. The semantics do not record that a rule itself was introduced by an event, nor that its revocation would require a distinct counter-event. As a result, OWL cannot distinguish between a law of nature and a law enacted yesterday.

This limitation can be stated as a theorem.

Proposition. There exists no OWL ontology $\mathcal{O}$ such that, for a class of actions A, the ontology entails both (i) that A was admissible prior to some event e and (ii) that A is now inadmissible *because* of e, without encoding e as an external meta-construct.

Sketch of proof. OWL entailment is invariant under permutation of axioms. If the inadmissibility of A is entailed, it is entailed timelessly. Any reference to a change in admissibility must therefore be represented as a change in ontology, not within ontology. The causal force of the event cannot be internalized.

This result clarifies why ontology versioning, governance, and policy systems built on OWL inevitably rely on procedural overlays, human authority, or ad hoc annotations. The ontology itself lacks the expressive power to say *why* something is forbidden now rather than merely asserting that it is forbidden.

26 A Worked OWL Encoding and Its Failure Mode

To make this limitation concrete, consider an attempt to encode commitment and refusal in OWL. Suppose we introduce the following classes and properties:

```
Class: Action
Class: RefusedAction SubClassOf: Action
```

```
ObjectProperty: forbids
    Domain: Event
    Range: Action
```

One might attempt to model refusal by asserting that an event forbids an action, and that forbidden actions are inadmissible. However, OWL provides no semantics for inadmissibility. At best, one can assert that forbidden actions are instances of a class with no allowed realizations, but this immediately leads to inconsistency rather than structured exclusion.

Alternatively, one might try to encode admissibility using modal-style patterns, introducing a class `AdmissibleAction` and axioms stating that certain actions are no longer admissible after an event. Yet OWL lacks event ordering and cannot express that admissibility is evaluated relative to a history prefix. Any such encoding either collapses into contradiction or degenerates into a static taxonomy of permitted versus forbidden actions.

By contrast, in an event-historical ontology, refusal is not a predicate on actions but a transformation of the future space. The formal object is not a class inclusion but a rewrite of admissible continuations:

$$\mathcal{F}(H \cdot \text{refuse}(A)) = \mathcal{F}(H) \setminus \{h' \mid A \in \text{enabled}(h')\}.$$

This operation has no analogue in description logic, because it is not truth-functional. It is constructive and asymmetric in time.

The practical implication is that OWL ontologies can describe outcomes of commitment, but not commitment itself. They can assert that an action is disallowed, but not that it has been disallowed by an irreversible act whose legitimacy, scope, and authority matter.

27 Toward a Two-Layer Ontology Architecture

The preceding analysis suggests a principled architectural resolution. Rather than extending OWL to do what it cannot, ontology engineering should adopt a two-layer design.

At the lower layer lies an event-historical kernel, responsible for recording commitments, refusals, and collapses as irreversible transformations of admissible futures. This kernel operates over histories, not states, and enforces authorization rules that are sensitive to the entire prefix of prior events. It is at this level that identity, accountability, and power are grounded.

At the upper layer lie classical ontologies expressed in OWL or related formalisms. These function as stabilized views generated by authorized collapse operations. They support efficient reasoning, classification, and interoperability precisely because they abstract away historical detail. Crucially, however, they are no longer treated as ontologically complete. Their authority is derived, not primitive.

This stratification mirrors the separation already present in many successful systems, but makes it explicit and principled. Version control systems distinguish commits from working trees; legal systems distinguish enacted law from codified statutes; distributed systems distinguish logs from materialized views. The RSVP framework unifies these practices under a single ontological theory.

28 Ontology Engineering as Governance of Futures

A final implication follows from taking irreversible histories seriously: ontology engineering becomes a normative discipline. Choosing an ontology is not merely choosing a vocabulary; it is choosing which futures remain intelligible and which are foreclosed.

When an ontology introduces a new distinction, deprecates a class, or enforces a constraint, it is performing a pop or refuse operation in the semantic space of its users. These acts have downstream consequences for data integration, institutional practice, and agent behavior. Treating ontology evolution as a purely technical activity obscures its role as a form of governance.

The event-historical framework provides tools for making this governance explicit. It allows ontology engineers to ask not only whether a model is consistent, but what commitments it makes irreversible, which identities it stabilizes, and which trajectories it excludes. This reframes debates about realism versus pragmatism, or universality versus context, in operational rather than metaphysical terms.

29 Closing Remarks

By extending ontology engineering beyond entity-centric and state-based assumptions, the RSVP framework offers a way to reconcile formal rigor with the realities of change, power, and agency. Its insistence on irreversible history does not reject classical ontologies, but situates them within a broader theory of becoming.

In domains where the past binds the future, ontology cannot be timeless. It must remember not only what is true, but what has been made impossible. Only then can it faithfully represent the structures it seeks to describe.

A   Admissible Histories and Entropy-Bounded Identity

This appendix provides a formal specification of admissible histories and clarifies the role of entropy as an ontological regulator of identity persistence. The goal is to make precise the sense in which RSVP treats identity not as an intrinsic property of entities, but as a constraint-stabilized phenomenon that exists only within bounded regions of historical possibility.

Let $\mathcal{E}$ be a countable set of event types, and let $\mathcal{H}$ denote the set of all finite event sequences over $\mathcal{E}$. A history $h \in \mathcal{H}$ is a totally ordered sequence

$$h = \langle e_1, e_2, \ldots, e_n \rangle.$$

Histories are prefix-closed: if $h \in \mathcal{H}$, then every prefix of h is also in $\mathcal{H}$. This prefix structure induces a partial order $(\mathcal{H}, \preceq)$, where $h \preceq h'$ if and only if h is a prefix of h'.

Admissibility is defined relative to a constraint function

$$\mathcal{A} : \mathcal{H} \to \mathcal{P}(\mathcal{E}),$$

where $\mathcal{A}(h)$ denotes the set of event types admissible after history h. A history $h \cdot e$ is admissible if and only if $e \in \mathcal{A}(h)$. This definition is intentionally non-Markovian: $\mathcal{A}$ may depend on the entire history, not merely on a bounded suffix or summary state.

Entropy enters the ontology through the cardinality and structure of admissible continuations. For a history h, define its future set

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

The entropy $S(h)$ of a history is a measure of the degeneracy of $\mathcal{F}(h)$ under an appropriate equivalence relation $\sim$, which identifies futures that are indistinguishable with respect to stabilized invariants. Intuitively, $S(h)$ quantifies how many materially distinct ways the world may still unfold given the commitments already made.

Identity in RSVP is not binary but regime-based. An identity predicate I is said to persist across a set of histories $\mathcal{H}_I \subseteq \mathcal{H}$ if and only if the entropy of admissible futures consistent with I remains below a threshold ϵ_I:

$$\forall h \in \mathcal{H}_I, \quad S(h \mid I) \leq \epsilon_I.$$

When entropy exceeds this bound, identity dissolvesnot because an entity ceases to exist, but because the constraints required to distinguish it from alternatives can no longer be maintained.

This formalism explains why identity is robust in low-entropy domains, such as classical mechanics or well-governed databases, and fragile in high-entropy domains, such as evolving machine learning systems or socio-technical institutions. Ontological failure in these domains is not an error of representation but a consequence of unconstrained future branching.

B   Comparison with BFO: Continuants, Occurrents, and the Failure of Time Symmetry

The Basic Formal Ontology (BFO) distinguishes between continuants, which persist through time, and occurrents, which unfold in time. While this distinction captures an important phenomenological difference, it presupposes that persistence itself is primitive. RSVP rejects this assumption.

In RSVP, there are no primitive continuants. What BFO calls a continuant corresponds to a region of history space in which entropy remains sufficiently low that certain invariants are preserved across admissible futures. Occurrents, meanwhile, correspond to sequences of events that restructure the admissible future space. The difference is quantitative and dynamical, not categorical.

This reconceptualization resolves several long-standing tensions in BFO-based ontology engineering. First, it eliminates the need for special persistence conditions attached to continuants. Persistence becomes an emergent property of constraint maintenance rather than a metaphysical axiom. Second, it provides a principled account of identity failure over time, such as in ontology version drift or organizational change, without invoking vague notions of partial survival.

Most importantly, RSVP rejects the implicit time symmetry present in BFO. In BFO, an occurrent is fully specified by its temporal extent, and nothing in the formalism distinguishes the past from the future. In RSVP, by contrast, the asymmetry between past and future is foundational. Past events are fixed prefixes; future events are constrained possibilities. This asymmetry is what allows RSVP to represent commitment, responsibility, and power as ontological phenomena rather than external annotations.

C   Ontology Versioning as Entropic Divergence

A persistent problem in ontology engineering is version drift: the failure of mappings between successive ontology versions to preserve meaning. Traditional accounts treat this as a problem of alignment or expressivity. RSVP reframes it as an entropic phenomenon.

Let $\mathcal{O}_1$ and $\mathcal{O}_2$ be successive ontology versions derived from a common ancestor. In a state-based view, one seeks a mapping $f : \mathcal{O}_1 \to \mathcal{O}_2$ that preserves truth conditions. In an event-historical view, the relevant object is the divergence of admissible futures induced by the changes.

Ontology evolution introduces new constraints and relaxes others, thereby reshaping $\mathcal{A}(h)$ for users operating under the ontology. When the induced future sets $\mathcal{F}_1(h)$ and $\mathcal{F}_2(h)$ diverge beyond a tolerable entropy bound, semantic alignment fails. This failure is not accidental. It reflects the fact that the two ontologies no longer govern the same space of possible practices.

This analysis explains why backward compatibility is costly and why ontology governance inevitably involves political and institutional negotiation. Aligning ontologies is not merely aligning vocabularies; it is aligning futures.

D Agent Identity and Learning Systems

The RSVP framework has direct implications for modeling agent identity, particularly in artificial learning systems. A learning agent is not defined by its parameter state at a moment in time, but by the irreversible commitments encoded in its training history, architectural constraints, and deployment context.

Standard machine learning models obscure this reality by allowing retraining, fine-tuning, and rollback without ontological consequence. RSVP insists that genuine agency requires the capacity to refuse certain updates, preserve commitments, and incur irreversible costs. An agent that can always be reset has no history in the ontological sense.

This observation clarifies why alignment, once achieved, is fragile under retraining, and why accountability cannot be grounded in state snapshots or loss functions. Only systems that maintain low-entropy identity across timeby constraining their own future update spacecan be meaningfully said to act.

E Concluding Perspective

Taken together, these formal developments reinforce the central thesis of this work: ontology is not the study of what exists, but of what can still happen. By grounding ontology in irreversible histories rather than static entities, RSVP provides a unified foundation for representing identity, agency, power, and meaning across domains.

The price of this unification is the abandonment of timelessness. Ontologies built on RSVP must remember not only their current commitments, but how those commitments came to be, and what alternatives were permanently ruled out along the way. This burden is not a defect. It is the cost of realism in a world where the past cannot be undone.

F OWL Expressivity and the Limits of State-Based Description

The contrast between RSVP and mainstream ontology engineering becomes especially clear when considered through the lens of the Web Ontology Language (OWL). OWL is fundamentally grounded in description logic, which is explicitly state-based, monotonic, and model-theoretic. An ontology in OWL specifies a set of constraints that define a class of admissible models, but it does not natively represent how one model becomes another, nor does it encode irreversible transitions between models.

From an RSVP perspective, this is not a minor technical limitation but a categorical mismatch. OWL assumes that ontological truth is timeless and that inference expands knowledge monotonically. By contrast, RSVP assumes that ontological structure is produced through irreversible events that both add and remove admissible futures. In other words, OWL reasons over what is true in all possible worlds, while RSVP reasons over which possible worlds have been permanently excluded.

This distinction manifests concretely in several well-known OWL limitations. OWL lacks a native notion of negation-as-refusal. While one may assert that an individual is not a member of a class, this assertion does not prevent future axioms from reintroducing that membership under

open-world semantics. In RSVP terms, OWL supports weak negation but not strong exclusion. There is no construct corresponding to an irreversible deletion of futures.

Similarly, OWL cannot represent path-dependent constraints. Class membership and property assertions are evaluated pointwise in a model, not relative to the history of prior assertions. As a result, OWL cannot naturally encode commitments such as this agent once violated constraint C and therefore may never perform action A again. Any attempt to do so requires reification of time or ad hoc provenance annotations, which remain semantically external to the logic.

This analysis suggests that OWL ontologies can be faithfully embedded within RSVP only under conditions of aggressive collapse, where historical detail is intentionally erased and only present-tense constraints are retained. In this sense, OWL corresponds to a low-entropy projection of an event-historical ontology, suitable for stable domains but structurally incapable of representing irreversible dynamics.

G   An Event-Historical OWL Profile

Despite these limitations, RSVP does not reject OWL outright. Instead, it provides a principled account of what OWL can and cannot represent, and how it may be used as a derived layer within a larger event-historical architecture.

One may define an RSVPOWL profile in which OWL axioms are interpreted not as eternal truths, but as collapse-stable invariants over histories. In this profile, an OWL class corresponds to an equivalence class of histories whose admissible futures preserve a given invariant. Property assertions describe constraints that hold across all histories within that equivalence class, but say nothing about how those histories were produced.

Under this interpretation, ontology versioning becomes a sequence of collapse and refinement operations rather than a simple replacement of axioms. Introducing a new OWL axiom corresponds to a pop event that excludes histories incompatible with the new constraint. Deprecating an axiom does not restore excluded histories; it merely collapses distinctions among surviving ones. This asymmetry captures the irreversibility of conceptual change that OWL itself cannot express.

Reasoning in such a profile remains decidable because OWL reasoning is applied only after collapse. The event-historical machinery operates outside the description logic, governing which collapsed models are admissible at all. This stratification preserves computational tractability while restoring ontological realism.

H   Worked Example: Identity Drift in a Learning Model Ontology

To illustrate the advantages of an event-historical ontology, consider the problem of representing the identity of a machine learning model across retraining cycles. In conventional ontology engineering, a model instance is identified by a URI, with properties describing architecture, training data, and performance metrics. Retraining is modeled either as a new instance or as an update to the existing one, with no principled criterion for identity preservation.

Within RSVP, this ambiguity dissolves. Each training run is an irreversible event that alters

the admissible future behavior of the system. Let h_0 denote the history up to initial deployment, and let e_{train} denote a retraining event. The post-training history $h_1 = h_0 \cdot e_{\text{train}}$ admits a future space $\mathcal{F}(h_1)$ that is generally incomparable to $\mathcal{F}(h_0)$.

Identity persistence is evaluated by comparing the entropy of divergence between these future spaces. If the retraining preserves a bounded set of invariantssuch as safety constraints or task scopethen the entropy increase may remain below the identity threshold ϵ_I, and the model may be treated as the same agent. If not, identity fails, and the retrained system is ontologically distinct, regardless of naming conventions.

This criterion explains why fine-tuning for robustness may preserve identity, while retraining on a new objective function does not. It also clarifies why accountability cannot be transferred automatically across model updates: responsibility attaches to histories, not labels.

I Ontology Engineering as Constraint Design

The RSVP framework ultimately reframes ontology engineering itself as a form of constraint design. Ontologists are not merely cataloging what exists; they are shaping the space of admissible futures for reasoning systems, organizations, and agents.

In this view, an ontology is successful not when it achieves maximal coverage or expressivity, but when it stabilizes meaning under expected entropy loads. Low-entropy domains benefit from rigid, entity-centric ontologies. High-entropy domains require flexible, history-aware formalisms that can tolerate identity drift and semantic reconfiguration without collapsing into inconsistency.

RSVP provides the conceptual and formal tools to navigate this design space. By treating irreversibility as primitive, it aligns ontology engineering with the realities of computation, social organization, and physical law. It explains why certain ontologies fail, not as a matter of poor modeling, but because they attempt to impose timeless structure on processes that are intrinsically historical.

J Closing Remarks

This document has extended the RSVP framework into the domain of formal ontology engineering, demonstrating how irreversibility, entropy, and history can serve as ontological primitives. By situating existing standards such as BFO and OWL as low-entropy subtheories, RSVP preserves their utility while revealing their limits.

More importantly, it offers a path forward. As artificial agents become adaptive, institutions become fluid, and knowledge systems evolve continuously, ontology must move beyond static entity catalogs. It must become a theory of admissible histories.

Irreversible histories are not an inconvenience to be abstracted away. They are the substrate from which meaning, agency, and reality itself are built.

K   Outlook: Toward Entropy-Aware Ontology Tooling

If ontology engineering is reconceived as the design of admissible histories rather than the enumeration of entities, then the practical tooling that supports ontology work must also evolve. Current ontology development environments, reasoners, and version-control practices implicitly assume that ontologies are static artifacts punctuated by reversible edits. RSVP suggests instead that ontology evolution is itself an irreversible process that accumulates commitments over time.

One immediate implication is the inadequacy of conventional diff-based ontology versioning. Textual or axiom-level diffs obscure the semantic fact that some changes permanently foreclose interpretations that were once admissible. An RSVP-aligned toolchain would treat ontology revisions as first-class events, recording not only what axioms were added or removed, but which regions of semantic possibility space were irrevocably excluded as a result. Rollback, in such a system, would be understood not as restoration but as the creation of a new branch whose future is constrained by the memory of what has already been ruled out.

Reasoning services would likewise become stratified. At the lowest level, standard OWL reasoners could still be employed, operating over collapsed representations to answer local consistency and entailment queries efficiently. Above this layer, an event-historical controller would manage authorization, refusal, and collapse, determining which ontology states are even admissible inputs to description-logic reasoning. This separation preserves decidability where it is possible while acknowledging that not all ontological questions are reducible to timeless inference.

L   Relation to Upper Ontologies and Foundational Categories

The RSVP framework also clarifies the role of traditional upper ontologies such as BFO. These systems excel at providing stable categoriesobject, process, role, dispositionthat support interoperability across biomedical and scientific domains. RSVP does not dispute their internal coherence; rather, it explains why their success is domain-bounded.

Upper ontologies function effectively where entropy is low and where identity conditions are relatively stable across time. In such regimes, collapse can be applied aggressively without semantic loss. RSVP predicts, however, that as domains become more dynamicincorporating learning systems, adaptive organizations, or socio-technical infrastructuresupper ontologies will increasingly require ad hoc extensions to manage change, provenance, and exception handling. These extensions are symptoms of an underlying mismatch between entity-first modeling and history-first reality.

Within RSVP, upper ontologies can be reinterpreted as coordinate charts on a deeper manifold of histories. They provide locally useful parameterizations but cannot serve as global foundations. This perspective opens the possibility of principled ontology translation: rather than mapping entities to entities, one maps invariants preserved under collapse. Translation failure, on this account, is not an engineering defect but an entropic divergence between domains.

M Implications for Governance, Compliance, and Alignment

Beyond technical ontology engineering, the RSVP approach has direct implications for governance and alignment in computational systems. Regulatory frameworks increasingly require traceability, accountability, and auditability, particularly in AI-driven decision systems. These requirements are fundamentally historical: they concern not only what a system did, but how it came to be in a position to do it.

State-based ontologies struggle to meet these demands because they treat compliance as a property of current configurations. RSVP instead treats compliance as a property of histories. A system is compliant if its entire lineage of commitments respects specified constraints. Violations are not transient states but irreversible events that alter the systems admissible future actions.

This reframing aligns naturally with concepts such as revocation of authority, loss of certification, and institutional memory. Once a constraint is violated, certain futures are permanently disallowed. Attempting to reset the system without acknowledging this history is not a neutral act; it is a collapse that must itself be authorized. Ontology thus becomes an instrument of governance, encoding not just categories but consequences.

N Limits and Open Problems

The RSVP framework is deliberately ambitious, and several open problems remain. Chief among them is the formal integration of entropy measures with existing logical frameworks in a way that preserves computational feasibility. While RSVP provides conceptual clarity, practical deployment will require careful approximation strategies and domain-specific thresholds.

Another challenge lies in user interaction. History-first ontologies demand new metaphors for understanding identity, change, and responsibility. The cognitive load imposed by explicit irreversibility may be nontrivial, especially for practitioners accustomed to reversible editing and abstraction. Designing interfaces that expose historical commitment without overwhelming users is an open design problem.

Finally, there is the question of empirical validation. RSVP makes strong claims about why certain ontology efforts succeed or fail in practice. These claims invite systematic study across domains such as biomedical informatics, AI lifecycle management, and socio-technical system modeling.

O Conclusion

By extending ontology engineering into the domain of irreversible histories, RSVP offers a coherent response to long-standing difficulties in representing change, agency, and meaning. It reframes ontologies not as mirrors of a static world, but as instruments that actively shape which worlds remain possible.

The central lesson is austere but generative: ontology cannot remain neutral with respect to time. Every representational choice excludes futures, whether acknowledged or not. RSVP simply insists that we take responsibility for those exclusions.

Irreversible histories are not an optional complication to be engineered away. They are the ontological ground on which any realistic theory of meaning, agency, or intelligence must stand.

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