Emergent Properties of Deterministic Representational Stabilization

Vol. 4. — Minimal Transparency, Observational State Entropy, and Cognitive Resilience

Samuel V. Passberg

April 3, 2026

Introduction

In informational and computational systems, the representation of state constitutes the primary interface through which system behavior is accessed and interpreted. As systems evolve toward increasing complexity and distribution, the relationship between internal state and its external representation becomes a central concern, requiring precise conditions under which system states are exposed, observed, and understood.

This work is part of a series that progressively establishes a formal framework for representational conditions in informational systems. The initial formulation introduces the Perceptive Vacuum as the structural absence of a determinable representational condition. This is followed by the Transition Stabilization Axiom, which defines the requirement for deterministic correspondence between internal state and representation. The Perceptual Stabilization Transition Architecture then provides the structural mechanism through which this condition is enforced, while subsequent work presents an architectural instantiation within Real-Time Gross Settlement systems.

The present volume examines the informational and cognitive consequences of the stabilization condition established in the preceding formulations. Rather than introducing new structural mechanisms, this work derives the properties that emerge when representational exposure is conditioned on deterministic equivalence with the authoritative state.

Within this scope, the analysis focuses on the structural conditions under which representational ambiguity is eliminated, the minimal form through which state may be expressed, and the implications of these conditions for the interpretation of system state. The resulting framework characterizes the relationship between representation, informational sufficiency, and interpretative stability without extending beyond the defined representational domain.

Keywords:
Deterministic Representational Validity; Perceptual Stabilization Transition Architecture; Deterministic Equivalence; Observational State Entropy; Minimal Transparency; Cognitive Resilience; Representational Non-Existence; Structural Non-Bypass Principle; Closed Logical Domain.

Technical Specifications:

Program Lineage: Deterministic Representational Validity Framework
Structural Basis: Transition Stabilization Axiom (TSA)
Formal Paradigm: Deterministic Representational Stabilization
Core Formal Object: Observational State Entropy H_{obs} over set S
Structural Configuration: Emergent Properties of $PSTA$
Evaluation Principle: Deterministic Equivalence Constraint
Derivation Scope: Minimal Transparency and Entropy Minimization
Encoding: LaTeX
Version: v1.0
Framework Reference: Perceptual Stabilization Transition Architecture
(DOI: 10.5281/zenodo.18918056)
ORCID: 0009-0002-4609-552X

Passberg, Samuel V. (2026). *Emergent Properties of Deterministic Representational Stabilization.* Vol. 4.

Table of Contents

1 Foundations of State and Consistency

In distributed and concurrent systems, the characterization of system behavior relies on the definition of state and the conditions under which it is considered consistent. These systems operate without a single point of control or observation, requiring formal frameworks to describe how states are formed, how events are ordered, and how system behavior is perceived as coherent. Within this context, the concepts of state, ordering, and consistency establish the foundational structure through which system execution is defined and analyzed.

1.1 State in Distributed Systems

In distributed systems, the notion of state is not confined to a single locus, but is composed across multiple components that evolve through interactions over time. Each component maintains a local state, and the global system state emerges from the aggregation of these distributed conditions, without a central point of direct observation.

The determination of system state therefore depends on the coordination and integration of information across distinct processes, where no single entity possesses complete knowledge of the overall system at all times. As a result, state in distributed systems is inherently partial and temporally dependent, reflecting the combined evolution of interacting components rather than a singular, globally accessible condition.

1.2 Ordering and Causality

In distributed systems, the absence of a global clock prevents the direct establishment of a total temporal order over system events. As a result, the interpretation of system behavior depends on the relationships between events, rather than on an absolute notion of time, requiring a structural framework to determine how events are ordered and related.

The concept of causality provides such a framework, defining a partial ordering of events based on their potential influence over one another. As formalized in the work of **Lamport, L.**, the "happens-before" relation establishes the conditions under which one event can be said to precede another, enabling the reconstruction of event sequences consistent with system execution. This ordering forms the basis for reasoning about system state evolution, ensuring that the relationships between events are preserved even in the absence of a global temporal reference.

1.3 Observable Consistency

In distributed systems, consistency defines the conditions under which system operations appear coherent when observed, ensuring that the effects of interactions are reflected in a manner that preserves the integrity of the system state. This notion of consistency is concerned with the relationship between the execution of operations and their externally observable effects, establishing whether system behavior can be regarded as correct from the perspective of its outputs.

One of the fundamental models of observable consistency is linearizability, as introduced by **Herlihy, M.** and **Wing, J.**, which defines a condition under which each operation appears to occur instantaneously at some point between its invocation and completion. Under this model, the system behavior can be understood as if all operations were executed in a sequential order that respects real-time constraints, providing a coherent and consistent view of system state despite the underlying concurrency.

2 System Observability

In dynamical and informational systems, the internal state is not directly accessible, but may be inferred through the observation of system outputs. The concept of observability establishes the conditions under which such inference is possible, defining the relationship between observable signals and the underlying system state. Within this framework, the analysis of system behavior relies on the ability to reconstruct internal states from externally available information.

2.1 State Reconstruction

In dynamical systems, the internal state is not directly accessible, but can be inferred from observable outputs produced by the system over time. These outputs provide indirect information about the underlying state, allowing for the reconstruction of system conditions without requiring direct access to internal variables.

State reconstruction therefore consists in establishing a correspondence between sequences of observable outputs and the internal configuration of the system. Through this process, the internal state may be determined from externally available information, such that observation enables the recovery of system conditions in a mediated, yet structurally consistent manner.

2.2 Mathematical Observability

The formalization of observability establishes the conditions under which the internal state of a system can be uniquely determined from its observable outputs. In control theory, observability is defined as the property that allows the reconstruction of the system state from a finite sequence of outputs, given knowledge of the system dynamics and output functions, as formalized in the work of **Kalman, R. E**.

Within this framework, observability provides a rigorous mathematical condition for state reconstruction, ensuring that the internal state can be inferred from externally available signals under specified structural conditions. The concept defines whether sufficient information is present in the outputs to determine the state, establishing a foundational criterion for the analysis of dynamical systems and their observable behavior.

2.3 Scope Limitation of Observability Models

Observability, as formally defined, is concerned with the reconstruction of internal system states from observable outputs, establishing whether sufficient information is present to determine the underlying state. Within this scope, the representational form through which outputs are exposed is treated as a direct carrier of system information, without introducing additional conditions governing its structure or eligibility for exposure.

As a result, observability models do not address the relationship between representational states and their interpretation at the observer level. The conditions under which a representation is exposed, and the implications of its structure for the determination of system state, remain outside the scope of these formulations. Observability therefore establishes the possibility of state reconstruction, but does not define the conditions governing how reconstructed states are represented or interpreted at the interface level.

3 Representation and State Interpretation

In informational systems, interaction with system state occurs through representational forms exposed at the interface. These representations mediate access to underlying system conditions, establishing the observable layer through which system behavior is interpreted. Within this framework, the interpretation of system state depends on the relationship between representational structures and the underlying states they express.

3.1 Representation of Informational State

In informational systems, the internal state is not directly accessible at the interface level, but is instead expressed through representational forms. These representations constitute externally observable projections of underlying system states, enabling interaction with and interpretation of the system without direct access to its internal structure.

A representational state does not correspond to the internal state itself, but to a constructed form derived from it, shaped by the mechanisms through which the system exposes information. As such, representation establishes the observable layer of the system, defining the conditions under which internal states become accessible in a mediated form, rather than as direct manifestations of the authoritative state.

3.2 Observer Interpretation

The observer does not access the internal state of the system directly, but engages with its representational form. Interpretation arises from the correspondence established between the observed representation and a possible underlying state, such that the observer infers system conditions through the structure and content of the representation.

Within this process, interpretation constitutes a mapping from representational states to assumed system states, constrained by the information made available at the interface. The observer's understanding of the system is therefore determined by the representational form, as no direct access to the authoritative state is available, and all inference operates through the mediated structure of representation.

3.3 Mental Model and Feedback

Through the process of interpretation, the observer forms an internal representation of the system state based on the observed representational form. This internal representation, or mental model, reflects the inferred condition of the system and serves as the basis for subsequent interaction, decision, and expectation regarding system behavior.

The consistency of this mental model depends on the stability and coherence of the representational form presented at the interface. As the observer relies exclusively on representation to infer system state, any variation in representational structure directly influences the formation and adjustment of the internal model. The alignment between representation and authoritative state therefore determines the reliability of the feedback loop through which the observer updates their understanding of the system.

4 Structural Gap in Representational Exposure

Existing frameworks establish consistent mechanisms for the definition of state, the ordering of events, the reconstruction of internal system conditions, and the interpretation of system behavior by observers. Within these formulations, representational states are treated as accessible projections of underlying system states, implicitly assumed to reflect the internal condition of the system without an explicit condition governing eligibility for exposure.

Existing approaches address ordering, observability, and interpretation of system states. The condition governing representational exposure prior to deterministic verification of equivalence with the authoritative state remains unaddressed. As a result, representational states may be presented independently of their correspondence to the authoritative state, admitting ambiguity in the interpretation of system state at the observer level.

5 Architectural Conditioning of Representation

The preceding sections establish that existing frameworks do not define a condition governing representational exposure. The present section introduces this condition, under which representation is admitted only upon equivalence with the authoritative state.

5.1 Representational Conditioning via PSTA

Representational exposure is not treated as a direct consequence of state availability, but as a conditionally governed transition. Within the Perceptual Stabilization Transition Architecture, the emergence of a representational state is structurally conditioned on its correspondence with the authoritative state, such that representation is not admitted by default, but only under defined equivalence conditions.

This conditioning operates at the representational boundary, where authoritative states produced within the system are projected into externally observable forms. The boundary functions as a structural constraint on exposure, ensuring that representational states are admitted only when the required condition is satisfied, independent of whether the observer is an internal system component or an external agent.

5.2 Equivalence Predicate $\Delta(a, r)$

The condition governing representational exposure is formalized through the equivalence predicate $\Delta(a, r)$, defined over the authoritative state $a \in \mathcal{A}$ and a candidate representational state $r \in \mathcal{R}$. The predicate evaluates whether the representational state satisfies the equivalence condition with respect to the authoritative state, establishing a binary outcome that determines eligibility for exposure.

Within this framework, $\Delta(a, r)$ operates as a structural gating condition rather than a passive verification mechanism. The evaluation of equivalence is not performed as an auxiliary check following exposure, but as a prerequisite for representational admission. As a result, the existence of a representational state at the interface is conditioned on the satisfaction of $\Delta(a, r)$, such that exposure is governed by equivalence rather than by the availability of state.

5.3 Representational Non-Existence Condition

When the equivalence predicate $\Delta(a, r)$ is not satisfied, no representational state is admitted at the exposure boundary. In this condition, the system does not produce an alternative or provisional representation; instead, representation is structurally withheld, such that no state is made available for observation in the absence of equivalence with the authoritative state.

This absence does not correspond to a lack of underlying system state, but to the non-existence of a representational state under the governing condition. The representational domain therefore admits no element $r \in \mathcal{R}$ for which $\Delta(a, r) = 0$, establishing that representational existence is contingent upon equivalence. As a result, the interface does not expose indeterminate or approximated states, but enforces a condition under which representation either exists in equivalence or does not exist at all.

6 Representational Stabilization

Given the conditioning of representational exposure established in the preceding section, stabilization follows as a direct consequence of the equivalence condition. Under this framework, representational states are admitted only when equivalence with the authoritative state is satisfied, establishing a structurally governed condition of representational stability.

6.1 Stabilization Condition

When the equivalence predicate $\Delta(a, r) = 1$, the representational state is admitted at the exposure boundary, establishing a condition under which the representation corresponds deterministically to the authoritative state. Under this condition, representational exposure does not arise as a projection of available state, but as a consequence of verified equivalence.

Stabilization therefore denotes the structural condition in which the representational state reflects the authoritative state without residual ambiguity. The admitted representation is not provisional or inferred, but corresponds to the authoritative state under the governing condition, such that exposure occurs only in the presence of equivalence.

6.2 Elimination of Perceptive Vacuum

The Perceptive Vacuum denotes the condition in which a representational state is available for observation while lacking a determinable correspondence to the authoritative state. Under such conditions, the observer is presented with a representation that admits multiple plausible interpretations, as no structural condition enforces equivalence prior to exposure.

Under the stabilization condition defined by $\Delta(a, r)$, the Perceptive Vacuum does not arise. When equivalence is satisfied, the representational state corresponds deterministically to the authoritative state; when equivalence is not satisfied, no representational state is admitted. As a result, the representational domain admits no state in which exposure occurs without correspondence, eliminating the conditions under which perceptual indeterminacy may emerge.

6.3 State V

State V denotes the representational condition established when the equivalence predicate $\Delta(a, r) = 1$ is satisfied, under which the representational state is admitted at the exposure boundary. Under this condition, the exposed representation corresponds uniquely and deterministically to the authoritative state, not as a result of inference or approximation, but as a consequence of structurally conditioned admission.

State V is therefore a binary condition of representational validity. A representational state is either admitted under equivalence, constituting *State V*, or it is not admitted at all. No intermediate or partially valid representational condition exists, and no representation is exposed without satisfying the equivalence condition. As a result, the representational interface admits no ambiguity, and the authoritative state is uniquely determined at the observer level.

7 Minimal Representational Transparency

Under the stabilization condition established in the preceding section, representational exposure admits a minimal sufficient form in which only those states required to establish equivalence with the authoritative state are present. Within this condition, representation is neither expanded nor reduced beyond what is necessary for determination, defining a minimal representational structure at the exposure boundary.

This condition is referred to as Minimal Transparency, denoting the minimal representational form under which the authoritative state is uniquely determined.

7.1 Minimal Sufficient Subset $S_{\mathbf{min}}$

Under the stabilization condition, the representational domain admits a subset of states that is sufficient to determine the authoritative state without residual ambiguity. This subset, denoted $S_{\text{min}} \subseteq S$, contains only those representational states that satisfy the equivalence condition with respect to the authoritative state, such that no additional states are required to establish a determinate correspondence.

The subset S_{min} is minimal in the sense that any further reduction would compromise the sufficiency condition, while any expansion would introduce redundant or indeterminate elements. Its specific composition is determined at the implementation boundary, while its structural role remains invariant: to define the minimal representational form under which the authoritative state is uniquely determined at the observer level.

7.2 Informational Sufficiency Criterion

Informational sufficiency is defined as the condition under which the representational subset admits a unique and determinate correspondence to the authoritative state. Under this criterion, the representational domain contains no additional states beyond those required to establish equivalence, such that the observer is presented with a representation that does not admit multiple plausible interpretations.

Within this framework, the subset S_{min} satisfies the informational sufficiency criterion by construction, as it contains only those states for which equivalence with the authoritative state is established. Any representational set that exceeds this subset introduces elements that are not required for determination, while any reduction below it compromises the ability to establish correspondence, thereby violating the sufficiency condition.

7.3 Structural Elimination of Interpretative Ambiguity

Interpretative ambiguity arises when a representational state admits multiple plausible correspondences to the authoritative state, such that the observer cannot determine a unique underlying condition. In such cases, the representational domain contains more than one candidate state consistent with the observed representation, allowing multiple interpretations to coexist at the observer level.

Under the informational sufficiency condition satisfied by S_{min}, this multiplicity does not arise. As the representational domain contains only those states that establish equivalence with the authoritative state, no alternative candidates are admitted. The representational form therefore corresponds uniquely to the authoritative state, eliminating the structural conditions under which interpretative ambiguity may emerge.

8 Observational State Entropy

Under the minimal representational transparency condition established in the preceding section, the representational domain admits a finite set of plausible states consistent with the observed representation. The ambiguity associated with this set can be expressed in quantitative terms, admitting a formulation of entropy defined over the space of admissible representational states.

8.1 Observational State Set S

The observational state set S is defined as the set of all representational states that are admissible at the exposure boundary under a given observation. This set comprises the states that remain structurally consistent with the observed representation, such that each element in S corresponds to a plausible authoritative state under the available representational form.

Within this framework, S characterizes the space of interpretative possibilities induced by the representational condition. When representational exposure is not governed by equivalence, multiple states may be admitted, expanding the set of plausible interpretations. Conversely, under the stabilization condition, the set collapses to those states that satisfy the equivalence condition, establishing the domain over which interpretative ambiguity may be evaluated.

8.2 Entropy Formulation

The ambiguity associated with the observational state set S admits a quantitative formulation in terms of entropy, defined over the cardinality of the set. This measure, denoted H_{obs}, expresses the number of distinguishable representational alternatives that remain consistent with the observed state, and is given by $H_{\text{obs}} = \log_2(|S|)$.

Within this formulation, H_{obs} does not represent uncertainty in a probabilistic sense, but the structural multiplicity of plausible states admitted under a given representational condition. As the cardinality of S increases, the number of admissible interpretations expands accordingly; conversely, when the set collapses under the equivalence condition, the entropy is minimized, reflecting the absence of interpretative ambiguity.

8.3 Structural Adaptation of Entropy

Shannon, C. E. formalizes entropy as a measure of uncertainty over a set of possible messages, establishing a quantitative framework defined on probability distributions over message spaces. In that formulation, entropy reflects the expected information content associated with the selection of a message from a given distribution.

In the present framework, entropy is not evaluated over probabilistic message distributions, but over the cardinality of the observational state set S, which encodes the set of plausible authoritative states consistent with a given representation. The measure $H_{\text{obs}} = \log_2(|S|)$ therefore expresses the structural multiplicity of admissible states at the representational level. This constitutes a structural adaptation of the entropy concept, in which the measure is defined over the space of representationally consistent states, rather than over stochastic processes of message generation.

8.4 Relation Between $S_{\min}$ and H_{obs}

Under the minimal representational transparency condition, the observational state set is restricted to the minimal sufficient subset $S_{\min}$, such that only those states that establish equivalence with the authoritative state are admitted. In this condition, the cardinality of the observational set is minimized, as no additional or alternative states are present beyond those required for deterministic correspondence.

As a result, the entropy H_{obs} attains its minimal value, reflecting the collapse of the space of plausible interpretations. When $S = S_{\min}$, the observational state set admits no multiplicity beyond the minimal sufficient condition, and the representational state corresponds uniquely to the authoritative state. The entropy measure therefore converges to its lower bound, establishing a condition in which interpretative ambiguity is structurally eliminated.

9 Informational Convergence

Under the equivalence condition $\Delta(a, r) = 1$, representational exposure is admitted only for states that correspond deterministically to the authoritative state, establishing the minimal sufficient subset $S_{\min}$ as the admissible representational domain. Within this condition, the observational state set is restricted to $S_{\min}$, such that no additional or alternative states are present beyond those required for determination. This restriction implies a minimal cardinality of the observational set, under which the entropy H_{obs} attains its lower bound. The representational condition therefore corresponds to a unified structural state in which equivalence, minimal sufficiency, and minimal entropy coincide, eliminating the space of interpretative ambiguity.

10 Cognitive Resilience

When the observational state entropy H_{obs} attains its minimal value, the representational condition corresponds to a state in which no alternative interpretations are admissible at the observer level. Under this condition, the representational form establishes a unique and determinate correspondence to the authoritative state, such that interpretation does not require selection among competing possibilities. The absence of interpretative multiplicity eliminates the need for inferential resolution, resulting in a reduction of cognitive load associated with state interpretation and establishing a stable and predictable representational condition.

This condition corresponds to a state of cognitive resilience, in which the observer is not required to resolve ambiguity or reconcile competing interpretations. Rather than denoting an increased capacity to manage uncertainty, cognitive resilience here emerges as a structural consequence of its absence. As described in models of human-system interaction proposed by **Norman, D. A.**, the stability of representation supports the formation of consistent mental models, such that a deterministic correspondence between representation and system state maintains alignment between observation and underlying condition. Under minimal entropy conditions, the representational interface admits no ambiguity, and the observer's interpretation remains structurally determined.

11 Positioning Within the Literature

This section situates the present formulation within existing theoretical frameworks addressing state, consistency, observability, information, and interpretation.

Lamport, L. formalizes the ordering of events and causal relationships in distributed systems, establishing a framework for reasoning about temporal consistency across independent processes. The model operates within the domain of event sequencing and state evolution under partial ordering. The condition governing representational exposure prior to deterministic verification remains outside the scope of this formulation.

Herlihy, M., Wing, J. define correctness conditions for concurrent operations through linearizability, establishing a model for ensuring consistency of shared data under concurrent access. The framework operates at the level of operation ordering and atomic visibility of state transitions. The eligibility of representational states for exposure prior to equivalence with an authoritative state remains outside the scope of this formulation.

Kalman, R. E. formalizes the concept of observability in dynamic systems, establishing conditions under which internal system states can be reconstructed from external outputs. The model operates within a mathematical framework relating system dynamics to measurable outputs. The ambiguity associated with the interpretation of representational states by an observer remains outside the scope of this formulation.

Shannon, C. E. formalizes the concept of entropy as a measure of uncertainty in information systems, establishing a quantitative framework for analyzing information transmission and encoding. The model operates within the domain of probabilistic distributions over message spaces. In the present formulation, this framework is structurally adapted to express ambiguity over sets of observationally admissible states, rather than uncertainty in communication channels.

Norman, D. A. formalizes the interaction between system representations and human cognitive processes, establishing a model of interpretation based on mental models and feedback. The framework operates at the interface between system behavior and human understanding. The structural conditioning of representational exposure as a determinant of interpretative stability remains outside the scope of this formulation.

Taken together, these frameworks establish the structural and interpretative territory within which representational exposure is established as a conditioned structural event, governed by equivalence with the authoritative state.

12 Conclusion

The Perceptual Stabilization Transition Architecture is defined as a structural condition governing representational exposure, under which representational states are admitted only upon deterministic equivalence with the authoritative state. Under this condition, representational stabilization emerges as a direct consequence, establishing a correspondence in which representation reflects the authoritative state without admitting alternative interpretations.

This condition gives rise to a minimal representational structure, characterized by the subset S_{min}, under which only the states required for deterministic correspondence are admitted. The associated observational state entropy H_{obs}, defined over the cardinality of admissible states, attains its minimal value in this condition, reflecting the absence of interpretative multiplicity within the representational domain.

Within this framework, cognitive resilience corresponds to the condition in which interpretation remains structurally aligned with the authoritative state, without requiring resolution of ambiguity or reconciliation of competing interpretations. The resulting formulation characterizes the relationship between representational conditioning, informational sufficiency, and interpretative stability as properties derived from a single structural condition, without extending beyond the defined representational domain. These conditions permit the exposure of state as a deterministically valid representational process rather than a static representation.

13 References

1. Lamport, L. (1978). *Time, Clocks, and the Ordering of Events in a Distributed System.* https://doi.org/10.1145/359545.359563

2. Herlihy, M., & Wing, J. (1990). *Linearizability: A Correctness Condition for Concurrent Objects.* https://doi.org/10.1145/78969.78972

3. Kalman, R. E. (1960). *A New Approach to Linear Filtering and Prediction Problems.* https://doi.org/10.1115/1.3662552

4. Shannon, C. E. (1948). *A Mathematical Theory of Communication.* https://doi.org/10.1002/j.1538-7305.1948.tb01338.x

5. Norman, D. A. (2013). *The Design of Everyday Things (Revised and Expanded Edition).* MIT Press. https://mitpress.mit.edu/9780465050659/the-design-of-everyday-things/

6. Passberg, S. V. (2026). *Formal Theory of Deterministic Representational Validity.* https://doi.org/10.5281/zenodo.18857240

7. Passberg, S. V. (2026). *Perceptual Stabilization Transition Architecture.* https://doi.org/10.5281/zenodo.18918056

8. Passberg, S. V. (2026). *Deterministic State Stabilization in RTGS Systems.* https://doi.org/10.5281/zenodo.19103871