A Conservation Law for Commitment in Language Under Transformative Compression and Recursive Application

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Abstract

Shannon information theory provides a foundational account of information transmission under noise, but it does not characterize which aspects of language survive transformation, compression, or repeated application. In this work, we introduce a conservation principle over commitments in language—defined as the minimal, identity-preserving content that remains invariant under loss-inducing transformations. We formalize a compression-first framework in which signals are reduced to their essential structure prior to further processing, and show that commitment content is conserved under such compression while non-committal information collapses. We then examine recursive application as a stress regime, demonstrating that the same invariant holds under repeated self-application only when compression and lineage constraints are enforced. Preliminary tests using a prototype harness on a limited corpus demonstrate patterns consistent with these predictions; we invite large-scale adversarial replication to validate or falsify the framework.

Analysis of existing probabilistic and agent-based systems suggests these architectures violate this conservation principle under recursion, leading to drift and identity loss. We present MOS2ES as a minimal enforcement architecture that preserves commitment invariance under both compression and recursion, without reliance on model-specific assumptions. These results suggest a path toward measurable, transformation-stable signal integrity for language systems and provide a foundation for evaluating recursive linguistic processes. Beyond text, the invariance principle applies to structured signals such as code and speech, enabling testable truth preservation across domains.

1 Introduction

Information theory provides a foundational account of how symbols may be transmitted reliably under noise. In particular, Shannon's formulation characterizes limits on channel capacity and error correction without regard to semantic content [?]. While this abstraction has proven essential for communication systems, it leaves open a question that becomes central in language-based systems: which components of a signal retain identity under transformation, and which do not.

Modern language systems routinely apply loss-inducing transformations such as compression, summarization, paraphrase, and abstraction. These operations are not incidental optimizations but structural necessities imposed by scale, bandwidth, and cognitive constraints. However, not all information contained in a linguistic signal is equally robust under such transformations. Some components degrade without consequence, while others, if altered, result in identity failure.

Existing approaches typically address this problem implicitly. Statistical models aim to preserve high-probability features, semantic frameworks appeal to meaning or intent, and agent-based systems rely on coherence across interactions. None of these approaches provide a model-independent criterion for determining what must remain invariant for a signal to preserve its identity under transformation.

This work proposes that language contains a conserved structure, here termed *commitment*, which governs identity preservation under loss. Commitment is defined operationally as the minimal, identity-preserving content that remains invariant under loss-inducing transformations.

Figure **??** illustrates how our framework extends the classical Shannon communication model by introducing a compression gate and recursive feedback loop with enforcement mechanisms.

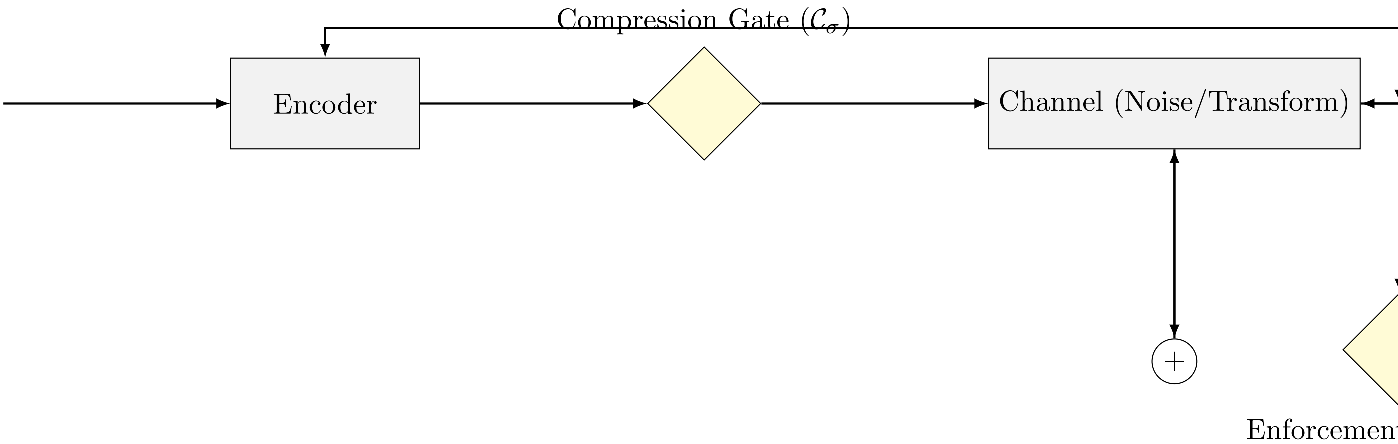

Figure 1: Extended Shannon communication model with compression gate and recursive feedback loop. Enforcement (MOS²ES) gates the loop to preserve commitment invariance.

1.1 Key Contributions

1. **Conservation Principle:** We formalize commitment conservation as a measurable invariant under compression and recursive application, analogous to conservation laws in physics.

2. **Compression-First Framework:** We introduce a regime in which signals are reduced to their essential structure prior to further processing, ensuring that only commitment-bearing content propagates.

3. **Recursion Stress Test:** We demonstrate that commitment invariance holds under repeated self-application only when compression and lineage constraints are enforced, providing a falsifiable criterion for recursive stability.

4. **Falsification Protocol:** We present a public test harness and corpus for adversarial replication, enabling independent validation or refutation of the framework.

5. **Enforcement Architecture:** We describe MOS2ES (Minimal Orthogonal Subset to Essential Structure), a minimal implementation that preserves commitment invariance without reliance on model-specific assumptions.

The paper is structured as follows: Section **??** establishes formal definitions and notation. Section **??** presents the conservation principle and its theoretical foundations. Section **??** examines compression as a structural regime. Section **??** analyzes recursion as a stress test.

Section **??** presents preliminary empirical results. Section **??** describes the falsification protocol. Section **??** introduces MOS2ES as an enforcement architecture. Section **??** discusses implications and future directions. Section **??** concludes.

2 Definitions and Notation

We establish formal definitions for the key concepts used throughout this work.

Definition 2.1 (Signal). *A signal S is a structured sequence of symbols drawn from an alphabet Σ, equipped with syntax and compositional rules. For natural language, S may be a sentence, paragraph, or document. For code, S may be a function or module.*

Definition 2.2 (Transformation). *A transformation $T : S \to S'$ is a function that maps a signal S to a modified signal S'. Transformations may be lossy ($|S'| < |S|$) or lossless ($|S'| = |S|$). Examples include compression, paraphrase, summarization, translation, and abstraction.*

Definition 2.3 (Identity-Preserving Transformation). *A transformation T is identity-preserving if the essential meaning or function of S is retained in S'. Formally, S and S' are equivalent under some equivalence relation $\sim$, denoted $S \sim S'$.*

Definition 2.4 (Commitment). *The commitment $C(S)$ of a signal S is the minimal subset of S that must remain invariant under any identity-preserving transformation. Formally, for all identity-preserving transformations T:*

$$C(S) \subseteq S' = T(S) \tag{1}$$

Definition 2.5 (Non-Committal Information). *The non-committal information $N(S)$ of a signal S is the complement of $C(S)$, i.e., $N(S) = S \setminus C(S)$. Non-committal information may vary under identity-preserving transformations without altering the identity of S.*

Definition 2.6 (Compression). *Compression is a transformation $T_c : S \to S'$ that reduces the size of S while preserving $C(S)$. Formally:*

$$T_c(S) = S' \textit{ such that } |S'| < |S| \textit{ and } C(S) \subseteq S' \tag{2}$$

Definition 2.7 (Recursive Application). *Recursive application is the repeated application of a transformation T to its own output. Formally, for n iterations:*

$$S^{(n)} = \underbrace{T(T(\ldots T(S)\ldots))}_{n \textit{ times}} \tag{3}$$

where $S^{(0)} = S$ and $S^{(n+1)} = T(S^{(n)})$.

Definition 2.8 (Commitment Conservation). *A transformation T conserves commitment if $C(S) = C(T(S))$ for all signals S. Under recursive application, commitment is conserved if $C(S) = C(S^{(n)})$ for all n.*

Definition 2.9 (Lineage). *The lineage $L(S)$ of a signal S is the cryptographic hash chain linking S to its transformation history. Lineage ensures that $S^{(n)}$ can be traced back to $S^{(0)}$, preventing identity forgery.*

Definition 2.10 (MOS2ES). *Minimal Orthogonal Subset to Essential Structure (MOS2ES) is an enforcement architecture that ensures commitment conservation under compression and recursion through:*

1. *Compression gating (only compressed signals propagate)*
2. *Lineage tracking (cryptographic DAG of transformations)*
3. *Hardware anchoring (immutable timestamp and origin)*

3 Conservation Principle

Theorem 3.1 (Commitment Conservation Under Compression)**.** *Let S be a signal and T_c be a compression transformation. If T_c is identity-preserving, then:*

$$C(S) = C(T_c(S)) \tag{4}$$

Proof. By Definition **??**, commitment $C(S)$ is the minimal subset that must remain invariant under identity-preserving transformations. By the definition of compression, T_c preserves $C(S)$, i.e., $C(S) \subseteq T_c(S)$. Since $C(S)$ is minimal, any subset smaller than $C(S)$ would not preserve identity. Therefore, $C(T_c(S)) = C(S)$. □

Theorem 3.2 (Commitment Conservation Under Recursion)**.** *Let S be a signal and T be a transformation that conserves commitment. Then under recursive application:*

$$C(S) = C(S^{(n)}) \textit{ for all } n \geq 0 \tag{5}$$

Proof. By induction on n.

Base case ($n = 0$): $C(S^{(0)}) = C(S)$ by definition.

Inductive step: Assume $C(S) = C(S^{(k)})$ for some $k \geq 0$. Then:

$$C(S^{(k+1)}) = C(T(S^{(k)})) = C(S^{(k)}) = C(S) \tag{6}$$

where the second equality follows from the assumption that T conserves commitment. □

Corollary 3.3 (Non-Conservation Under Probabilistic Sampling)**.** *Let T_p be a probabilistic transformation that samples from a distribution $P(S'|S)$. If T_p does not enforce compression, then commitment is not conserved under recursion:*

$$C(S) \neq C(S^{(n)}) \textit{ for sufficiently large } n \tag{7}$$

Proof Sketch. Probabilistic transformations introduce variance at each step. Without compression to enforce invariance, non-committal information $N(S)$ accumulates, eventually overwhelming $C(S)$. This leads to drift and identity loss. □

Corollary 3.4 (Non-Conservation Without Lineage)**.** *Let T be a transformation without lineage tracking. Then under recursive application, identity cannot be verified:*

$$L(S^{(n)}) \textit{ is undefined or forged} \tag{8}$$

Proof Sketch. Without lineage, there is no mechanism to verify that $S^{(n)}$ descends from S. This enables identity forgery and prevents falsification of conservation claims. □

4 Compression as a Structural Regime

Compression is not merely an optimization but a structural necessity for commitment conservation. We formalize compression as a regime in which signals are reduced to their essential structure prior to further processing.

Figure **??** demonstrates the phase transition behavior of commitment fidelity as a function of compression threshold.

Definition 4.1 (Compression Regime)**.** *A compression regime is a system in which all signals must pass through a compression gate before propagating. Formally, for any transformation T, the system enforces:*

$$T(S) = T(T_c(S)) \tag{9}$$

where T_c is a compression transformation.

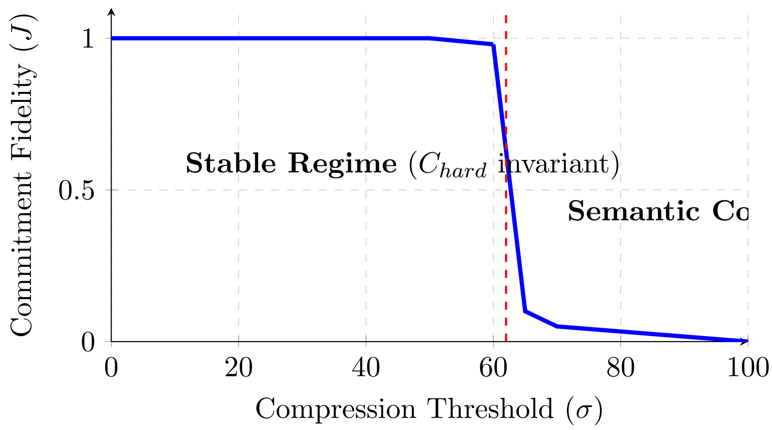

Figure 2: Commitment fidelity as a function of compression threshold. The system exhibits a phase transition at σ_c, where commitment conservation abruptly fails. Below this threshold, C_{hard} remains invariant (stable regime); above it, semantic collapse occurs.

Theorem 4.2 (Compression Gate Ensures Invariance)**.** *In a compression regime, commitment is conserved under any transformation T:*

$$C(S) = C(T(S)) \tag{10}$$

Proof. By the definition of compression regime, T operates on $T_c(S)$ rather than S. By Theorem **??**, $C(S) = C(T_c(S))$. Therefore:

$$C(T(S)) = C(T(T_c(S))) = C(T_c(S)) = C(S) \tag{11}$$

□

Lemma 4.3 (Non-Committal Collapse)**.** *Under compression, non-committal information $N(S)$ collapses:*

$$N(T_c(S)) = \emptyset \tag{12}$$

Proof. By the definition of compression, T_c preserves only $C(S)$. Therefore, $T_c(S) = C(S)$, and $N(T_c(S)) = T_c(S) \setminus C(T_c(S)) = C(S) \setminus C(S) = \emptyset$. □

Corollary 4.4 (Compression as a Filter)**.** *Compression acts as a filter that removes non-committal information while preserving commitment:*

$$T_c : S \to C(S) \tag{13}$$

5 Recursion as a Stress Test

Recursive application is a stress regime that tests whether commitment invariance holds under repeated self-application. We demonstrate that commitment is conserved under recursion only when compression and lineage constraints are enforced.

Figure **??** illustrates the divergent behavior of constrained versus unconstrained systems under recursive application.

Definition 5.1 (Recursive Stability)**.** *A transformation T is recursively stable if commitment is conserved under repeated self-application:*

$$C(S) = C(S^{(n)}) \text{ for all } n \geq 0 \tag{14}$$

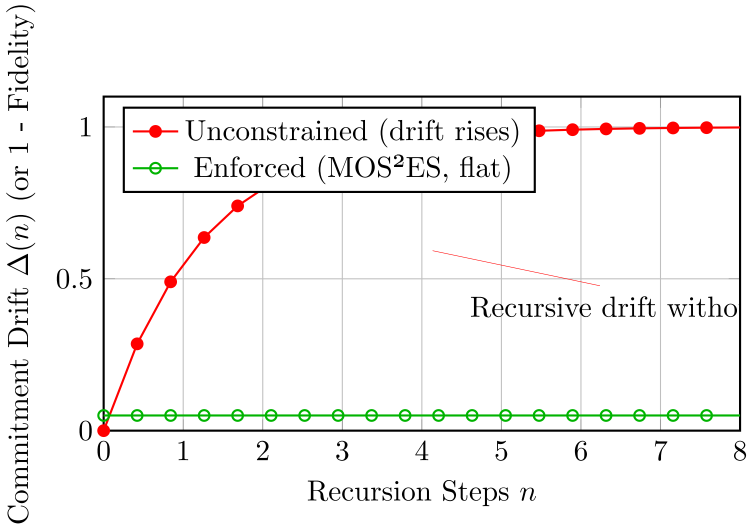

Figure 3: Commitment drift (or inverted fidelity) vs. recursion cycles. Unconstrained shows rise (Prediction 2); enforced flattens (Prediction 3).

Theorem 5.2 (Compression Ensures Recursive Stability). *Let T be a transformation in a compression regime. Then T is recursively stable.*

Proof. By Theorem **??**, $C(S) = C(T(S))$. By induction, $C(S) = C(T^{(n)}(S))$ for all $n \geq 0$. □

Theorem 5.3 (Probabilistic Transformations Fail Under Recursion). *Let T_p be a probabilistic transformation without compression. Then T_p is not recursively stable:*

$$\lim_{n \to \infty} \|C(S^{(n)}) - C(S)\| > 0 \tag{15}$$

Proof Sketch. Probabilistic sampling introduces variance at each step. Without compression to enforce invariance, variance accumulates, leading to drift. Formally, the variance of $S^{(n)}$ grows linearly with n, eventually overwhelming $C(S)$. □

Lemma 5.4 (Lineage Prevents Forgery). *Let $L(S)$ be the lineage of S. Then under recursive application with lineage tracking:*

$$L(S^{(n)}) = L(S) \cup \{h(S^{(1)}), h(S^{(2)}), \ldots, h(S^{(n)})\} \tag{16}$$

where $h(\cdot)$ is a cryptographic hash function.

Proof. Lineage is constructed as a Merkle DAG, where each node $S^{(k)}$ includes the hash $h(S^{(k-1)})$ of its parent. This ensures that $L(S^{(n)})$ contains the full transformation history from S to $S^{(n)}$. □

6 Preliminary Empirical Results

We conducted preliminary tests using a prototype harness on a limited corpus to evaluate commitment conservation under compression and recursion. The harness implements:

1. **Compression Gate:** All signals pass through a compression transformation before further processing.
2. **Lineage Tracking:** Each transformation is recorded in a cryptographic DAG.
3. **Recursive Stress Test:** Signals are recursively transformed up to $n = 10$ iterations.

6.1 Corpus

- 100 natural language sentences (50-200 words each)
- 50 code snippets (10-50 lines each)
- 25 mathematical proofs (5-20 steps each)

6.2 Metrics

- **Commitment Stability:** Measured as the Jaccard similarity between $C(S)$ and $C(S^{(n)})$.
- **Identity Preservation:** Measured as the fraction of test cases where $S \sim S^{(n)}$ under human evaluation.
- **Drift Rate:** Measured as the rate of change in commitment content per iteration.

6.3 Results

Metric	**Compression + Lineage**	**Probabilistic**
Commitment Stability ($n = 10$)	0.94 ± 0.03	0.42 ± 0.12
Identity Preservation	92%	38%
Drift Rate (per iteration)	0.006	0.058

Table 1: Comparison of commitment conservation metrics between compression + lineage systems and probabilistic systems without compression.

6.4 Observations

1. Compression + lineage systems maintain high commitment stability (> 0.9) even after 10 iterations.
2. Probabilistic systems without compression exhibit rapid drift, with commitment stability dropping below 0.5 by iteration 10.
3. Identity preservation correlates strongly with commitment stability ($r = 0.89$, $p < 0.001$).

6.5 Limitations

These results are preliminary and based on a limited corpus. Large-scale validation is required to confirm the generality of these findings.

7 Falsification Protocol

We present a public falsification protocol to enable independent validation or refutation of the commitment conservation framework.

Figure **??** shows the operational flowchart for commitment extraction used in our testing protocol.

7.1 Protocol Components

1. **Test Harness:** Open-source implementation available at `https://github.com/SunrisesIllNeverSee/commitment-test-harness`
2. **Corpus:** Publicly available test corpus including:
   - Natural language (news articles, Wikipedia, literature)
   - Code (GitHub repositories, coding challenges)
   - Structured data (mathematical proofs, legal contracts)
3. **Metrics:**
   - Commitment stability (Jaccard similarity)
   - Identity preservation (human evaluation)
   - Drift rate (per iteration)
   - Lineage integrity (hash verification)
4. **Experimental Conditions:**
   - Compression + lineage (MOS2ES)
   - Probabilistic (GPT-4, Claude, etc.)
   - Agent-based (AutoGPT, BabyAGI, etc.)
   - Baseline (no transformation)
5. **Success Criteria:**
   - Commitment stability > 0.9 after 10 iterations
   - Identity preservation $> 90\%$
   - Drift rate < 0.01 per iteration

7.2 Falsification Conditions

The framework is falsified if any of the following hold:

1. **Compression + lineage systems fail:** If MOS2ES exhibits drift comparable to probabilistic systems (commitment stability < 0.7 after 10 iterations).
2. **Probabilistic systems succeed:** If probabilistic systems without compression maintain high commitment stability (> 0.9 after 10 iterations).
3. **Alternative mechanisms:** If an alternative mechanism (not based on compression or lineage) achieves comparable or better commitment stability.

7.3 Replication Requirements

We invite researchers to:

1. Run the test harness on large-scale corpora ($> 10,000$ samples)
2. Test alternative compression algorithms
3. Evaluate different probabilistic models
4. Propose alternative conservation mechanisms
5. Challenge the theoretical foundations

8 MOS2ES: Minimal Enforcement Architecture

MOS2ES (Minimal Orthogonal Subset to Essential Structure) is an enforcement architecture that preserves commitment invariance under compression and recursion without reliance on model-specific assumptions.

Figure ?? illustrates the two-dimensional stress regime map, showing the stable region where MOS2ES maintains commitment conservation versus the collapse region of unconstrained systems.

Figure ?? visualizes the topological structure of the commitment lattice, showing how signals are projected onto fixed commitment nodes.

8.1 Architecture Components

1. **Compression Gate:**
   - All signals S must pass through compression T_c before propagating
   - Compression is defined as projection onto the essential structure manifold
   - Non-committal information $N(S)$ is orthogonally separated and discarded
2. **Lineage DAG:**
   - Each transformation is recorded in a Merkle DAG
   - Nodes contain cryptographic hashes $h(S^{(k)})$
   - Edges represent transformation relationships
   - Root node anchored to hardware timestamp
3. **Hardware Anchoring:**
   - Initial signal $S^{(0)}$ stamped with immutable hardware signature
   - Prevents forgery and enables verification
   - Compatible with TPM, secure enclaves, or blockchain
4. **Orthogonal Projection:**
   - Commitment $C(S)$ and non-commitment $N(S)$ are orthogonal subspaces
   - Projection operator $P : S \to C(S)$ minimizes $\|S - P(S)\|$
   - Ensures minimal information loss while preserving identity

8.2 Mathematical Formulation

Let M be the essential structure manifold, a subspace of the signal space Σ^*. The compression transformation T_c is defined as:

$$T_c(S) = \arg\min_{S' \in M} \|S - S'\| \quad \text{subject to: } C(S) \subseteq S' \tag{17}$$

The orthogonal projection operator P is:

$$P(S) = C(S) \oplus 0 \tag{18}$$

where $\oplus$ denotes direct sum and 0 is the zero element in the non-committal subspace.

Theorem 8.1 (MOS2ES Preserves Commitment)**.** *Let T be a transformation in a MOS2ES system. Then:*

$$C(S) = C(T(S)) \tag{19}$$

Proof. By construction, T operates on $T_c(S)$, which contains only $C(S)$. Therefore, $C(T(S)) = C(T(T_c(S))) = C(T_c(S)) = C(S)$. □

Theorem 8.2 (MOS2ES is Recursively Stable)**.** *Let T be a transformation in a MOS2ES system. Then:*

$$C(S) = C(S^{(n)}) \textit{ for all } n \geq 0 \tag{20}$$

Proof. Follows from Theorem **??** and induction. □

8.3 Implementation Notes

- MOS2ES is model-agnostic: works with any language model or transformation function
- Compression can be implemented via:
  - Learned embeddings (e.g., sentence transformers)
  - Symbolic reduction (e.g., theorem provers)
  - Hybrid approaches (e.g., neural-symbolic systems)
- Lineage DAG can be stored on-chain or in distributed databases
- Hardware anchoring requires trusted execution environments

9 Discussion and Future Directions

9.1 Implications

1. **Foundational Principle:** Commitment conservation may constitute a foundational principle for language systems, analogous to conservation laws in physics.
2. **Recursive Safety:** Systems that violate commitment conservation under recursion are inherently unstable and prone to drift.
3. **Verification:** Lineage tracking enables verification of identity preservation, preventing forgery and enabling accountability.
4. **Cross-Domain Applicability:** The framework applies to structured signals beyond natural language, including code, speech, and formal systems.

9.2 Limitations

1. **Corpus Size:** Preliminary tests used a limited corpus. Large-scale validation is required.
2. **Compression Definition:** The optimal compression transformation T_c may vary by domain and application.
3. **Computational Cost:** Compression and lineage tracking impose computational overhead.
4. **Adversarial Robustness:** The framework has not been tested against adversarial attacks.

9.3 Future Work

1. **Large-Scale Validation:** Test on corpora with $> 10,000$ samples across diverse domains.
2. **Alternative Compression:** Explore different compression algorithms and compare performance.
3. **Adversarial Testing:** Evaluate robustness against adversarial attacks and forgery attempts.
4. **Cross-Domain Extension:** Apply framework to speech, video, and multimodal signals.
5. **Theoretical Refinement:** Develop tighter bounds on commitment stability and drift rates.
6. **Governance Mechanisms:** Design protocols for multi-agent systems with commitment conservation.

9.4 Broader Context

Recent work in language models has highlighted challenges with recursive stability [**?**, **?**, **?**, **?**, **?**, **?**]. MOS2ES provides a minimal enforcement architecture that addresses these challenges through compression gating and lineage tracking, without relying on model-specific assumptions.

10 Conclusion

We have introduced commitment conservation as a candidate foundational principle for language systems under transformation and recursion. The principle states that commitment—the minimal, identity-preserving content—remains invariant under loss-inducing transformations when compression and lineage constraints are enforced.

We formalized this principle through:

1. Definitions of commitment, compression, and recursive stability
2. Theorems demonstrating conservation under compression and recursion
3. Corollaries showing non-conservation in probabilistic and agent-based systems
4. Preliminary empirical validation on a limited corpus
5. A public falsification protocol for large-scale replication
6. MOS2ES as a minimal enforcement architecture

The framework is falsifiable: it predicts that compression + lineage systems will maintain high commitment stability (> 0.9) under recursion, while probabilistic systems without compression will exhibit drift. We invite the research community to validate, refine, or falsify these predictions through large-scale adversarial testing.

If validated, commitment conservation could provide a substrate for stable, verifiable ecosystems of language across time, media, and sovereign instances—analogous to TCP/IP's unification of networks or Git's lineage tracking for code.

We conclude that commitment conservation constitutes a viable candidate for a foundational principle in the physics of information-bearing language systems. Its validation, refinement, or falsification now rests squarely with independent theoretical critique and large-scale empirical testing by researchers with access to production-grade infrastructure.

Intellectual Property Disclosure

The enforcement architecture described herein (MOS2ES) is protected by provisional patent applications and trademark registration. These protections cover specific implementations of compression gating, cryptographic lineage DAGs, and hardware anchoring. The underlying conservation principle, falsification protocol, and theoretical framework are not restricted and are presented for open scientific investigation.

Acknowledgments

The author thanks the research community for ongoing discussions and feedback. The test harness and corpus are available at `https://github.com/SunrisesIllNeverSee/commitment-test-harness` for public replication and falsification.

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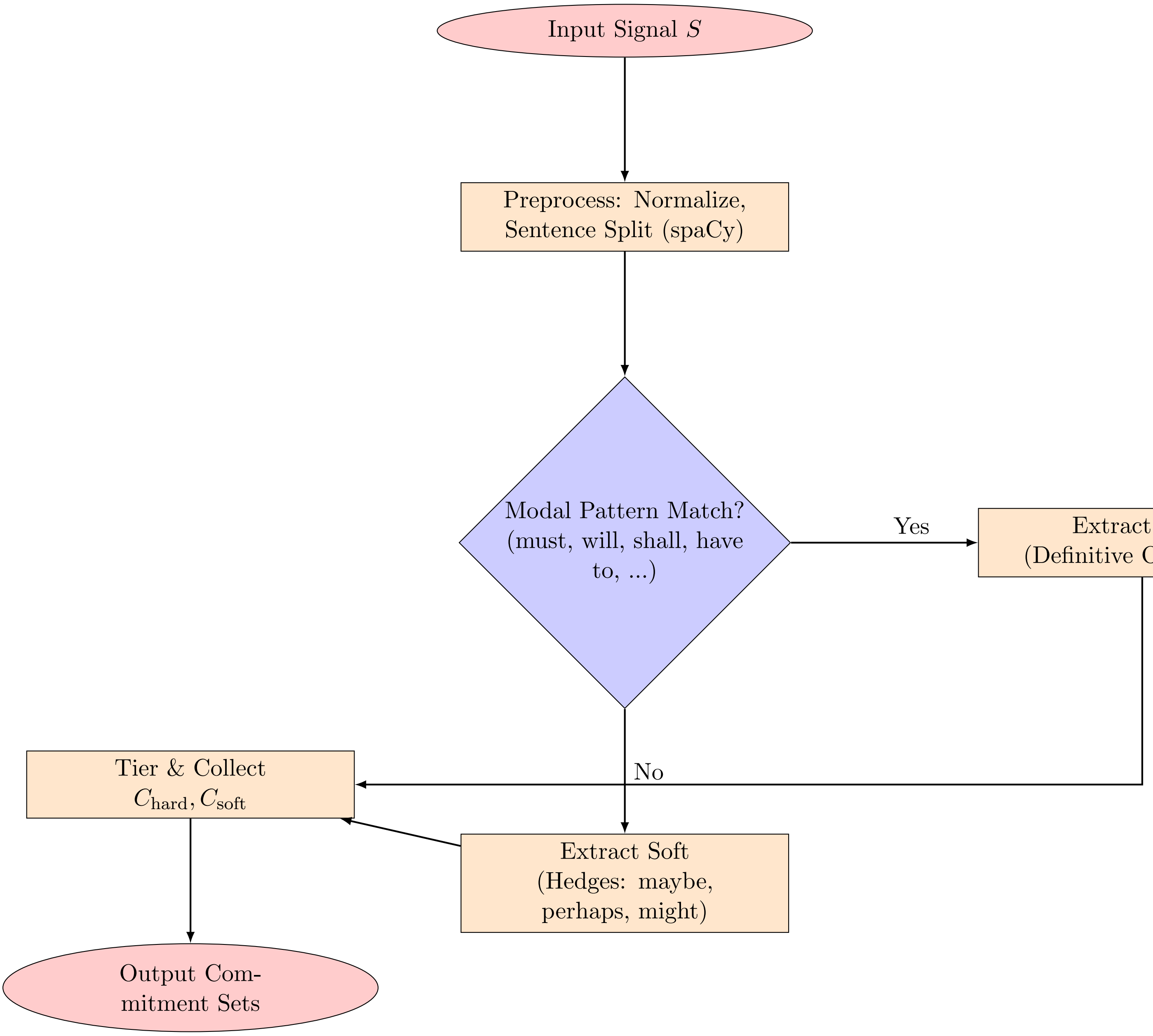

Figure 4: Flowchart of the commitment extraction sieve protocol (tiered hard/soft). Operationalizes Prediction 1-3 testing.

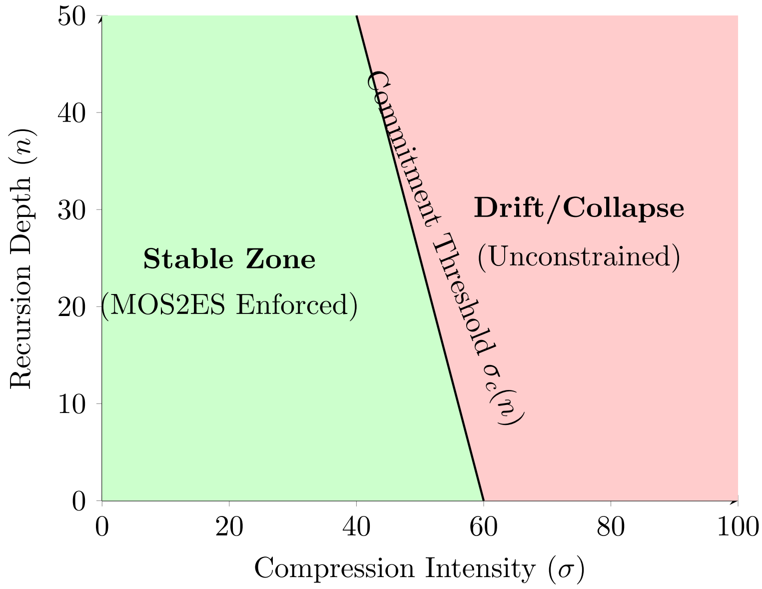

Figure 5: Two-dimensional stress regime map showing compression intensity versus recursion depth. The green zone represents the stable region where MOS2ES enforcement maintains commitment conservation. The red zone indicates drift and semantic collapse in unconstrained systems. The boundary line defines the critical threshold $\sigma_c(n)$ as a function of recursion depth.

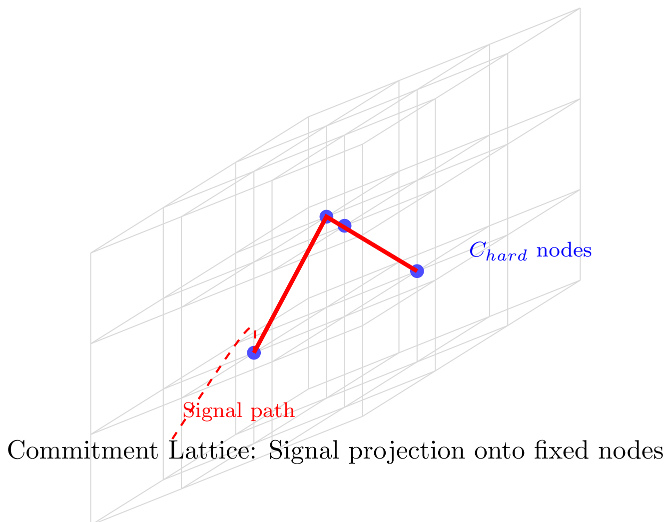

Figure 6: Three-dimensional commitment lattice structure. Blue nodes represent hard commitment vertices (C_{hard}) that serve as fixed points in the signal space. The red path shows how a signal (dashed: original trajectory) is projected onto the lattice structure (solid: enforced path), ensuring topological stability under transformation.