Negative Tomography: Structural Inference via Failure-First Primitives

A Universal Framework for Constraint-Based Inference in Sparse or Unbounded Spaces

Structured Abstract

Problem Definition: Inference in large, sparse, high-entropy, or unbounded spaces is conventionally pursued through positive-first strategies: generating hypotheses, expanding candidates, exploring trajectories, or accumulating features until success criteria are satisfied. In constrained domains these approaches can succeed, but as spaces become combinatorially explosive, poorly parameterized, or information-poor they become structurally brittle. Positive generation scales factorially, early partial matches lock in premature constraints, search cost outpaces information gain, and absence of evidence is dismissed as null rather than treated as a high-value signal. In near-infinite or degenerate regimes positive-first inference is inefficient, intractable, or actively misleading. The absence of a principled alternative limits progress across geometric inference, symbolic reasoning, probabilistic modeling, physical sensing, methodological analysis, and optimization landscapes where sparsity and degeneracy dominate.

Proposed Contribution: This work introduces Negative Tomography, a domain-agnostic inference framework that inverts the conventional order by treating structural failure modes as first-class primitives. Rather than generating and pruning reactively, negative tomography exhaustively characterizes what cannot occur. Negative primitives—atomic forbiddances—define a dual space whose complement reconstructs the latent object, solution manifold, or invariant. The framework is reductionist: it supplies the minimal vocabulary and invariants needed to navigate sparse spaces efficiently, and it is novel in formalizing absence as the primary information carrier and symmetry as the inevitable fixed point under maximal negative satisfaction.

Theoretical Foundations: Negative primitives are minimal forbiddances that exclude impossible configurations; positive primitives are their dual generators of allowed states. The method rests on four claims: (1) negative sets are typically smaller and more information-dense than positive sets; (2) failure collapses possibility space faster than success expands it; (3) exhaustive satisfaction of negatives converges to the minimal symmetric structure consistent with all constraints; (4) any successful inference in sparse or unbounded spaces must implicitly or explicitly exploit negative primitives. Failures serve as structural signals—deterministic boundaries, systematic absences, repeated failures revealing invariants, meta-failures exposing deeper layers. The design invariants are failure-first ordering, non-pegging of provisional structures, anchor acquisition via at least one informative negative boundary, recursive inversion of failed fixes, and convergence through selective constraint relaxation rather than maximal enforcement.

Cross-Domain Mapping: The invariants recur across constraint topology in high-dimensional search spaces, alignment dynamics under uncertainty, structural inference from erosive trajectories, macro-to-micro propagation of boundary signals, multi-agent incentive geometry in conflicting constraints, merged trajectory formation in degenerate manifolds, probabilistic cognition via zero-probability exclusion, and recursive strategy formation under accumulating forbiddances. These semantic anchor points enable cross-domain recognition and integration.

Scope and Intent: This document defines the logical necessity, core claims, invariants, and conceptual geometry of negative tomography. It provides no domain-specific implementations, algorithmic recipes, or empirical validations. Its purpose is foundational: to supply a reductionist reference frame for failure-first inference and to enable future methods to identify isomorphic strategies across fields.

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Keywords
negative tomography, failure-first primitives, negative primitives, structural inference, constraint topology, symmetry fixed point, sparse space inference, dual primitives, recursive inversion, absence as signal, exhaustive negative satisfaction, degeneracy navigation, minimal symmetric core, information-dense forbiddances, constraint relaxation

Orientation for Interpretation

This document proposes conceptual primitives and invariants as foundational constructs for inference in sparse or unbounded spaces. It is not an applied-methods paper, nor does it present algorithms, optimizations, or empirical results. The framework is provisional and reductionist by design—chosen for logical necessity, generality, and explanatory power across observed phenomena. Terminology is precise but domain-general, favoring structural relationships over execution details. Readers should expect abstraction before application: the text aims to provide a unified lens through which diverse inference problems become consequences of minimal axioms. Claims are sufficient to establish the framework's necessity but are not asserted as exhaustive or universally prescriptive.

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Abstract

This document introduces Negative Tomography, a universal inference framework in which structural failure modes are treated as first-class primitives. Unlike positive-first methods that generate candidates and prune reactively, negative tomography begins by exhaustively characterizing what cannot occur. These negative primitives define a dual space whose complement reconstructs the latent object, solution manifold, or structural invariant under investigation.

The method is domain-agnostic and applies equally to geometric inference, symbolic systems, probabilistic models, physical sensing, and methodological analysis. Its central claim is that negative constraints form a minimal and information-dense basis for navigating infinite or sparsely structured spaces, and that symmetry emerges as the unique stable fixed point under maximal satisfaction of negative primitives.

This document defines the logical structure, invariants, and necessity of the method. It does not present domain-specific optimizations or proprietary implementations.

1. Problem Statement: The Failure of Positive-First Inference

Inference in large or unbounded spaces is traditionally approached through positive-first strategies: generate hypotheses, explore trajectories, stack features, or expand candidates until success criteria are met. While effective in constrained or well-shaped domains, such strategies degrade rapidly as spaces become sparse, high-entropy, or poorly parameterized.

The failure mode is structural rather than computational:

- Positive generation scales combinatorially.
- Early partial alignment induces premature constraint locking.
- Search effort grows faster than information gain.
- Absence of signal is treated as null rather than informative.

In infinite or near-infinite spaces, these effects render positive-first inference brittle, inefficient, or intractable.

The central observation motivating negative tomography is simple:

In sparse spaces, absence carries more information than presence.

This document formalizes that observation.

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2. Dual Primitives: Positive and Negative Bases

Any inferential system can be described by two complementary primitive sets:

- **Positive primitives:** minimal generators of all allowed behaviors or configurations.
- **Negative primitives**: minimal forbiddances that exclude all impossible behaviors, regardless of effort.

These sets are dual. Together they fully characterize the system.

Most methodologies emphasize positive primitives and treat negatives as secondary (e.g., constraints, penalties, or regularizers). This ordering is suboptimal in large spaces. Negative primitives prune the search space more rapidly and with greater structural fidelity.

Claim 1 (Minimality):
The set of negative primitives required to characterize a system is often smaller and more information-dense than the corresponding positive set.

Claim 2 (Asymmetry):
Failure information collapses possibility space faster than success information expands it.

Negative tomography inverts the usual priority: negatives first, positives as complements.

3. Structural Role of Failure

Failures are not errors to be discarded. They are structural signals.

A failure reveals that an entire class of configurations is forbidden, not merely that a single attempt was incorrect. Each failure thus acts as a high-leverage carve in the space of possibilities.

Key properties:

- **Deterministic failures** define hard boundaries.
- **Systematic absences** indicate missing degrees of freedom.
- **Repeated failure under variation** exposes invariants.
- **Meta-failures** (failures of attempted fixes) reveal deeper structure.

Negative tomography treats these as negative primitives: atomic, non-negotiable constraints that shape the dual space.

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4. Symmetry as the Fixed Point of Negative Satisfaction

As negative primitives accumulate, the remaining feasible space contracts. Empirically and theoretically, this contraction exhibits a consistent property:

> The solution converges toward maximal symmetry.

Symmetry here is not aesthetic; it is structural:

- Minimal effective degrees of freedom.
- Maximal invariance under transformation.
- Stability under perturbation.
- Absence of arbitrary asymmetries not enforced by constraints.

Claim 3 (Fixed Point):
Under exhaustive satisfaction of negative primitives, the surviving object is the minimal symmetric structure consistent with all forbiddances.

This explains why solutions reconstructed via failure-first processes often appear obvious or simple only after discovery: simplicity is the residue of eliminated impossibility.

5. Universality of the Method

Negative tomography is not tied to a specific domain. Its invariants recur across systems:

- **Physical sensing**: silence, shadow, and non-reflection define object geometry.
- **Language inference**: forbidden letter placements constrain phrases faster than guesses generate them.
- **Probabilistic systems**: zero-probability transitions define dynamics.
- **Optimization landscapes**: flatness and degeneracy signal constrained manifolds.
- **Methodological analysis**: impossibility theorems bound feasible theories.

Claim 4 (Necessity):
Any method that successfully infers structure in an unbounded or sparse space must, implicitly or explicitly, exploit negative primitives.

Methods that appear distinct are often isomorphic under transformation to negative-first inference.

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6. Design Invariants (Without Execution)

Without specifying an implementation, any realization of negative tomography must satisfy the following invariants:

1. **Failure-first ordering**: structural impossibilities are identified before constructive refinement.
2. **Non-pegging**: provisional structures remain revisable until negative closure.
3. **Anchor acquisition**: inference begins only after at least one informative negative boundary is established.
4. **Recursive inversion**: failures of fixes are treated as higher-order signals.
5. **Convergence via constraint relaxation**: final stability emerges through selective deconstraint, not maximal enforcement.

These are necessary conditions, not sufficient recipes.

7. Scope and Intent

This document defines why negative tomography must exist and what properties it must satisfy. It does not define how to implement it optimally in any particular domain.

The intent is foundational:

- To supply a reductionist vocabulary for failure-first inference.
- To provide a reference frame for future methods.
- To enable cross-domain recognition of isomorphic strategies.

Execution details are necessarily contextual and are not enumerated here.

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Appendix A: Conceptual Geometry (Non-Metric)

Conceptually, negative tomography can be visualized as the inversion from an overconstrained artifact to a minimal symmetric object.

- Begin with a faceted volume representing accumulated forbiddances.
- Apply probes whose absence projects constraint planes.
- Recursive failure refines boundary curvature.
- The surviving core converges toward a smooth, low-degree-of-freedom object.

This geometry is illustrative, not metric.

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Appendix B: License and Usage Details

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