

# Audit Policies and Evaluation Criteria

Specification-Complete

Universal Stochastic Predictor (USP)

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Audit Scope: USP v2.1.0-RC1

## Abstract

**Policy Strictness:** ZERO-HEURISTICS (STRICT: 0% Fallback Tolerance)

This document defines the complete set of 36 audit policies derived exclusively from the authoritative specification corpus. All policies are strict, deterministic, and verifiable without subjective interpretation.

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# 1 Source Specification Corpus (Authoritative)

All policies below are derived from the complete specification set in:

- `doc/latex/specification/Stochastic_Predictor_Theory.tex`
- `doc/latex/specification/Stochastic_Predictor_Implementation.tex`
- `doc/latex/specification/Stochastic_Predictor_IO.tex`
- `doc/latex/specification/Stochastic_Predictor_API_Python.tex`
- `doc/latex/specification/Stochastic_Predictor_Python.tex`
- `doc/latex/specification/Stochastic_Predictor_Test_Cases.tex`
- `doc/latex/specification/Stochastic_Predictor_Tests_Python.tex`

**Critical Rule:** No external sources are used. If a requirement does not appear in the specification corpus, it is not a policy.

## 2 Policy Index

1. Configuration Sourcing (Zero-Heuristics)
2. Configuration Immutability (Locked Subsections)
3. Validation Schema Enforcement
4. Atomic Configuration Mutation Protocol
5. Mutation Rate Limiting and Rollback
6. Walk-Forward Validation (Causal)
7. CUSUM Dynamic Threshold with Kurtosis
8. Signature Depth Constraint (M in [3,5])
9. Sinkhorn Epsilon Bounds
10. CFL Condition for PIDE Schemes
11. 64-bit Precision Enablement
12. Stop-Gradient for Diagnostics
13. Kernel Purity and Statelessness
14. Frozen Signal Detection and Recovery
15. Catastrophic Outlier Rejection (20 sigma)
16. Minimum Injection Frequency (Nyquist Soft Limit)
17. Staleness Policy and Degraded Mode Recovery (TTL)
18. Secret Injection via Environment Variables
19. Snapshot Integrity (SHA-256) and Validation
20. Non-Blocking Telemetry and I/O
21. Hardware Parity Audit Hashes
22. Emergency Mode on Singularities (Holder Threshold)
23. Entropy-Driven Capacity Expansion (DGM)
24. Dynamic Sinkhorn Regularization Coupling
25. Entropy Window and Learning Rate Scaling (JKO)
26. Load Shedding (Kernel D Depth Set)
27. Deterministic Execution and PRNG Configuration
28. Dependency Pinning (Exact Versions)
29. Five-Layer Architecture Enforcement
30. Snapshot Atomicity and Recovery (I/O)
31. Meta-Optimization Checkpoint Integrity
32. TPE Resume Determinism
33. Telemetry Flags and Alerts (Required Fields)
34. XLA No Host-Device Sync in Orchestrator
35. Vectorized vmap Parity
36. JIT Cache Warmup Guarantees

### 3 Configuration and Validation Policies

#### 3.1 Policy #1: Configuration Sourcing (Zero-Heuristics)

**Source:** `Stochastic_Predictor_I0.tex` (Configuration Mutation Protocol) and `Stochastic_Predictor_API` (PredictorConfig)

**Policy Statement:** All numerical parameters, thresholds, and algorithmic decisions must be derived from configuration values. No implicit or silent defaults are allowed at runtime.

**Audit Criteria:**

- **Fail** if any operational threshold is hardcoded without config mapping.
- **Pass** if all `PredictorConfig` fields are mapped from config and validated.

#### 3.2 Policy #2: Configuration Immutability (Locked Subsections)

**Source:** `Stochastic_Predictor_I0.tex` (Invariant Protection)

**Policy Statement:** The following subsections are immutable and must not appear in optimizer search space:

- `[core]`: `float_precision`, `jax_platform`
- `[io]`: `snapshot_path`, `telemetry_buffer_maxlen`, `credentials_vault_path`
- `[security]`: `telemetry_hash_interval_steps`, `snapshot_integrity_hash_algorithm`, `allowed_mutation_rate_per_hour`
- `[meta_optimization]`: `max_deep_tuning_iterations`, `checkpoint_path`, `mutation_protocol_version`

**Audit Criteria:**

- **Fail** if locked parameters are mutated or included in search space.
- **Pass** if mutation validation rejects locked updates.

#### 3.3 Policy #3: Validation Schema Enforcement

**Source:** `Stochastic_Predictor_I0.tex` (Validation Schema)

**Policy Statement:** All configuration mutations must pass strict schema validation: types, ranges, constraints, immutability, and interdependencies.

**Mandatory Rules (Examples):**

- `cusum_k`  $\in [0.3, 1.5]$
- `dgm_width_size`  $\in [32, 256]$  and power of 2
- `stiffness_low`  $<$  `stiffness_high`
- `signature_depth`  $\in \{3, 4, 5\}$

**Audit Criteria:**

- **Fail** if schema validation is bypassed or incomplete.
- **Pass** if validation rejects invalid updates with explicit errors.

#### 3.4 Policy #4: Atomic Configuration Mutation Protocol

**Source:** `Stochastic_Predictor_I0.tex` (Atomic TOML Update Algorithm)

**Policy Statement:** Configuration mutations must follow the 5-phase POSIX atomic protocol:

1. Validation

2. Backup
3. Temp write with `O_EXCL` and `fsync`
4. `os.replace`
5. Audit log

**Audit Criteria:**

- **Fail** if any phase is missing (backup, fsync, replace, audit log).
- **Pass** only if all phases are implemented.

### 3.5 Policy #5: Mutation Rate Limiting and Rollback

**Source:** `Stochastic_Predictor_I0.tex` (Rate Limiting and Safety Guardrails)

**Policy Statement:**

- Max 10 mutations per hour
- Min 1000 steps between mutations
- Relative change  $\leq 50\%$  (except discrete  $\pm 1$ )
- Rollback if RMSE increases  $> 30\%$  within 500 steps

**Audit Criteria:**

- **Fail** if any guardrail is missing or disabled.

## 4 Validation and Algorithmic Policies

### 4.1 Policy #6: Walk-Forward Validation (Causal)

**Source:** `Stochastic_Predictor_Implementation.tex` and `Stochastic_Predictor_Tests_Python.tex`

**Policy Statement:** K-Fold and random splits are prohibited. Validation must be rolling walk-forward with future-only test windows and step size  $H$ .

**Audit Criteria:**

- **Fail** if any non-causal split exists.
- **Pass** only if train/test are strictly ordered and non-overlapping.

### 4.2 Policy #7: CUSUM Dynamic Threshold with Kurtosis

**Source:** `Stochastic_Predictor_Implementation.tex` and `Stochastic_Predictor_Python.tex`

**Policy Statement:** CUSUM threshold must be dynamic and kurtosis-adjusted:

$$h_t = k \cdot \sigma_{\text{resid}} \cdot (1 + \ln(\kappa_t/3))$$

with  $k \in [3, 5]$  and rolling window size 252.

**Audit Criteria:**

- **Fail** if threshold is constant or missing kurtosis adjustment.
- **Pass** if dynamic formula and window are enforced.

### 4.3 Policy #8: Signature Depth Constraint (M in [3,5])

**Source:** `Stochastic_Predictor_Implementation.tex`

**Policy Statement:** Signature truncation depth  $M$  must be in  $\{3, 4, 5\}$ .

**Audit Criteria:**

- **Fail** if outside range is allowed.
- **Pass** if range enforced at config validation.

### 4.4 Policy #9: Sinkhorn Epsilon Bounds

**Source:** `Stochastic_Predictor_Implementation.tex` and `Stochastic_Predictor_Test_Cases.tex`

**Policy Statement:** Entropic regularization  $\varepsilon$  must satisfy  $10^{-4} \leq \varepsilon \leq 10^{-1}$  and include underflow protection.

**Audit Criteria:**

- **Fail** if epsilon bounds are not validated.

### 4.5 Policy #10: CFL Condition for PIDE Schemes

**Source:** `Stochastic_Predictor_Implementation.tex`

**Policy Statement:** Time step must satisfy the generalized CFL condition:

$$\Delta t \leq \frac{C_{\text{safe}} \cdot (\Delta x)^2}{2 \cdot \sup |\sigma(x)|^2 + \sup |b(x)| \cdot \Delta x}$$

with  $C_{\text{safe}} \approx 0.9$ .

**Audit Criteria:**

- **Fail** if CFL validation is missing.

## 5 JAX and Numerical Precision Policies

### 5.1 Policy #11: 64-bit Precision Enablement

**Source:** `Stochastic_Predictor_Python.tex`

**Policy Statement:** `jax_enable_x64` must be enabled for Malliavin and signature computations.

**Audit Criteria:**

- **Fail** if global x64 is not enabled at startup.

### 5.2 Policy #12: Stop-Gradient for Diagnostics

**Source:** `Stochastic_Predictor_Python.tex`

**Policy Statement:** All diagnostic and telemetry computations must apply `jax.lax.stop_gradient`.

**Audit Criteria:**

- **Fail** if diagnostics do not use `stop_gradient`.

### 5.3 Policy #13: Kernel Purity and Statelessness

**Source:** `Stochastic_Predictor_Python.tex` (kernels are pure XLA kernels)

**Policy Statement:** Kernels must be pure and stateless functions compatible with JAX transformations.

**Audit Criteria:**

- **Fail** if kernels perform I/O or mutate external state.



## 6 Robustness and Circuit Breaker Policies

### 6.1 Policy #14: Frozen Signal Detection and Recovery

**Source:** `Stochastic_Predictor_I0.tex`

**Policy Statement:** If  $N_{\text{freeze}} \geq 5$  identical values occur, detect frozen signal, emit event, freeze Kernel D, do not update weights, enable degraded mode. Recovery when variance  $> 0.1 \cdot \text{Var}_{\text{historical}}$  for 2 steps.

**Audit Criteria:**

- **Fail** if any required action is missing.

### 6.2 Policy #15: Catastrophic Outlier Rejection (20 sigma)

**Source:** `Stochastic_Predictor_I0.tex`

**Policy Statement:** If  $|y_t| > 20\sigma$ , discard input, keep inertial state, emit critical alert.

### 6.3 Policy #16: Minimum Injection Frequency (Nyquist Soft Limit)

**Source:** `Stochastic_Predictor_I0.tex` and `Stochastic_Predictor_Test_Cases.tex`

**Policy Statement:** Minimum injection frequency must be enforced based on WTMM scales and  $C_{\text{besov}}$ . Violation freezes Kernel D and emits alert before Holder error exceeds 10%.

### 6.4 Policy #17: Staleness Policy and Degraded Mode Recovery (TTL)

**Source:** `Stochastic_Predictor_I0.tex` and `Stochastic_Predictor_Tests_Python.tex`

**Policy Statement:** If  $\text{TTL}(y_{\text{target}}) > \Delta_{\text{max}}$ , cancel JKO update, freeze weights, set degraded mode. Recovery only when  $\text{TTL} < 0.8 \cdot \Delta_{\text{max}}$ .

## 7 Security and I/O Policies

### 7.1 Policy #18: Secret Injection via Environment Variables

**Source:** `Stochastic_Predictor_IO.tex`

**Policy Statement:** Credentials must be injected via environment variables. No secrets in source, config, or logs. `.env` must be gitignored.

### 7.2 Policy #19: Snapshot Integrity (SHA-256) and Validation

**Source:** `Stochastic_Predictor_IO.tex` and `Stochastic_Predictor_API_Python.tex`

**Policy Statement:** Snapshots must include SHA-256 hash and validation before load. Corrupt snapshots must be rejected with cold-start fallback.

### 7.3 Policy #20: Non-Blocking Telemetry and I/O

**Source:** `Stochastic_Predictor_IO.tex` and `Stochastic_Predictor_API_Python.tex`

**Policy Statement:** Telemetry and snapshot I/O must be non-blocking and decoupled from compute threads.

### 7.4 Policy #21: Hardware Parity Audit Hashes

**Source:** `Stochastic_Predictor_IO.tex`

**Policy Statement:** SHA-256 parity hashes of critical state must be logged at configurable intervals using canonical float64 serialization.

## 8 Adaptive and Emergency Mode Policies

### 8.1 Policy #22: Emergency Mode on Singularities (Holder Threshold)

**Source:** `Stochastic_Predictor_Theory.tex` and `Stochastic_Predictor_Tests_Python.tex`

**Policy Statement:** If Holder exponent falls below  $H_{\min}$ , force Kernel D weight to 1.0 and switch to Huber cost until recovery hysteresis.

### 8.2 Policy #23: Entropy-Driven Capacity Expansion (DGM)

**Source:** `Stochastic_Predictor_Theory.tex` and `Stochastic_Predictor_Test_Cases.tex`

**Policy Statement:** Capacity must scale with entropy ratio  $\kappa$  using:

$$\log(WD) \geq \log(W_0D_0) + \beta \log(\kappa), \quad \beta \in [0.5, 1.0]$$

### 8.3 Policy #24: Dynamic Sinkhorn Regularization Coupling

**Source:** `Stochastic_Predictor_Implementation.tex`

**Policy Statement:**

$$\varepsilon_t = \max(\varepsilon_{\min}, \varepsilon_0(1 + \alpha\sigma_t))$$

### 8.4 Policy #25: Entropy Window and Learning Rate Scaling (JKO)

**Source:** `Stochastic_Predictor_Implementation.tex`

**Policy Statement:** Entropy window and learning rate must scale with volatility:

- `entropy_window`  $\geq c \cdot L^2 / \text{ema\_variance}$
- `learning_rate`  $< 2 \cdot \text{sinkhorn\_epsilon} \cdot \text{ema\_variance}$

### 8.5 Policy #26: Load Shedding (Kernel D Depth Set)

**Source:** `Stochastic_Predictor_API_Python.tex` and `Stochastic_Predictor_Tests_Python.tex`

**Policy Statement:** Kernel D must support depth set  $M \in \{2, 3, 5\}$  with warmup precompile to avoid JIT cache misses.

## 9 System Configuration Policies

### 9.1 Policy #27: Deterministic Execution and PRNG Configuration

**Source:** `Stochastic_Predictor_API_Python.tex`

**Policy Statement:** Deterministic PRNG and reduction settings must be configured before importing JAX.

### 9.2 Policy #28: Dependency Pinning (Exact Versions)

**Source:** `Stochastic_Predictor_Python.tex`

**Policy Statement:** All dependencies must be pinned to exact versions. Open ranges are forbidden.

### 9.3 Policy #29: Five-Layer Architecture Enforcement

**Source:** `Stochastic_Predictor_Python.tex`

**Policy Statement:** Implementations must use the five-layer structure: api, core, kernels, io, tests.

## 10 Snapshot and Meta-Optimization Policies

### 10.1 Policy #30: Snapshot Atomicity and Recovery (I/O)

**Source:** `Stochastic_Predictor_Tests_Python.tex`

**Policy Statement:** Snapshots must be written to temp, fsync, and atomically renamed. Recovery must ignore torn temp files and load last valid snapshot.

### 10.2 Policy #31: Meta-Optimization Checkpoint Integrity

**Source:** `Stochastic_Predictor_API_Python.tex` and `Stochastic_Predictor_Tests_Python.tex`

**Policy Statement:** TPE checkpoints must include SHA-256 sidecar validation and fail on mismatch.

### 10.3 Policy #32: TPE Resume Determinism

**Source:** `Stochastic_Predictor_Test_Cases.tex` and `Stochastic_Predictor_Tests_Python.tex`

**Policy Statement:** Checkpoint resume must be bit-exact: best params, objective values, and trial history must match uninterrupted run.

### 10.4 Policy #33: Telemetry Flags and Alerts (Required Fields)

**Source:** `Stochastic_Predictor_API_Python.tex` and `Stochastic_Predictor_IO.tex`

**Policy Statement:** Telemetry must include `degraded_inference`, `emergency_mode`, `regime_change`, and `mode_collapse_warning` flags.

## 11 XLA and JAX Performance Policies

### 11.1 Policy #34: XLA No Host-Device Sync in Orchestrator

**Source:** `Stochastic_Predictor_Tests_Python.tex`

**Policy Statement:** Orchestrator outputs must remain on device; no host synchronization in hot path.

### 11.2 Policy #35: Vectorized vmap Parity

**Source:** `Stochastic_Predictor_Tests_Python.tex`

**Policy Statement:** Batched vmap execution must be bit-exact with sequential execution.

### 11.3 Policy #36: JIT Cache Warmup Guarantees

**Source:** `Stochastic_Predictor_Tests_Python.tex`

**Policy Statement:** Load shedding warmup must precompile all depths with cache hit rate  $\geq 99\%$ .

## 12 Audit Rule

### Critical Enforcement:

Any policy violation results in audit failure. Only checks explicitly derived from the specification corpus are permitted.

### 12.1 Verification Protocol

1. Run `code_alignement.py` to validate all 36 policies
2. Verify 100% pass rate (36/36)
3. Fix VSCode errors before commit
4. Update LaTeX docs if public API changes
5. Stage, commit, push with meaningful message

### 12.2 Implementation Reference

All audit logic is implemented in:

- `tests/scripts/code_alignement.py` - 36 `CODE_AUDIT_POLICIES`
- `tests/scripts/scope_discovery.py` - Auto-discovery utilities