Predictability Horizons:
A Resource-Bounded Theory of Singularities

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Abstract

We formalize “singularity” as a *prediction horizon* for resource-bounded agents: a period when the minimal compute for useful forecasts exceeds capacity. We connect the definition to compression (MDL/Information Bottleneck) and to the Phaneron substrate (novelty outruns consolidation), provide an operational detector (Singularity Index, SI) with numeric criteria and proxy signals, analyze sensitivity, and sketch a historical case study (Internet 1990s). The result is a practical, testable framework that reframes singularity from rhetoric into measurement.

1 Introduction

The phrase *technological singularity* spans everything from sober forecasting limits to sci-fi prophecy [**? ? ?**]. We strip away the mystique and define a singularity as a *prediction horizon* for a bounded agent: the point where the minimal compute required for forecasts surpasses the agent’s capacity. This reframing turns a grand narrative into a measurable phenomenon.

Phaneron lens. In the Phaneron substrate—a single-layer meaning model—horizons appear when novelty influx $\phi(t)$ outruns consolidation $\mu(t)$: compression fails, conflict rises, and semantic throughput drops. Abstraction discovery (which reduces description length) and capacity increases (tooling, compute, collaboration) push the horizon back outward.

Contributions. (i) A resource-bounded formalism: minimal compute C, capacity K, and the Singularity Index (SI); (ii) an operational detector with numeric criteria and proxy signals; (iii) sensitivity analysis (tolerance, capacity, detectors); (iv) a case-study plan for the Internet transition; (v) implications for governance and Phaneron.

2 Formal framework

Let $C^{(t,H,\varepsilon)}$ denote the *minimal computation* needed to achieve an error $\leq \varepsilon$ for forecasts over $[t, t+H]$, minimized over feasible algorithms/models. Let K denote the agent’s effective capacity (time/energy/compute/coordination).

Definition 1 (Prediction horizon)**.** *A horizon occurs at t if $\exists H > 0$ s.t. $C^{(t,H,\varepsilon)>K}$ while $C^{(t-\delta,H,\varepsilon)\leq K}$ for small $\delta > 0$.*

Definition 2 (Singularity Index)**.** $\mathrm{SI}(t, H, \varepsilon) = C^{(t,H,\varepsilon)/K}$. *Sustained* $\mathrm{SI} \geq 1$ *indicates a horizon for* (H, ε).

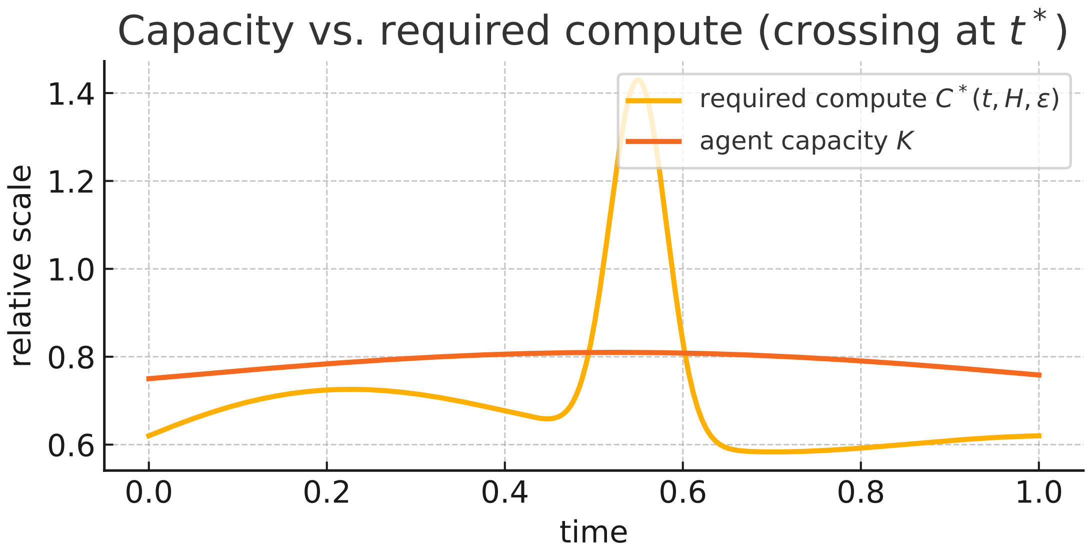

Figure 1: Capacity vs. required compute: a crossing induces a horizon.

Compression view. In MDL terms, forecastability improves when minimal code-length $L^{(t,H,\varepsilon)}$ drops via abstraction discovery; the Information Bottleneck perspective formalizes the trade-off between compression and relevance.

3 Operational detector and methods

3.1 Methods at a glance

Inputs: fit-cost curves $\hat{C}(t, H, \varepsilon)$; capacity audit K; proxy indices (dispersion, error floor, half-life, churn, compression stress, semantic FPS, consolidation deficit).
Outputs: $\widehat{\mathrm{SI}}(t, H, \varepsilon)$; horizon alarms; recovery estimates.

1. Choose ε bands and horizons H tied to decisions.
2. Measure $\hat{C}$ (train/update/forecast time or energy) on rolling windows.
3. Compute $\widehat{\mathrm{SI}} = \hat{C}/K$; run change-point detection (CUSUM or BOCPD).
4. Require sustained crossings and corroboration: dispersion ↑, error floor ↑, half-life ↓, churn ↑, compression stress ↑, consolidation deficit ↑.
5. Declare horizon; estimate recovery when proxies stabilize and SI<1.
6. Record interventions (abstractions discovered; K increases) for post-mortems.

3.2 Numeric criteria

3.3 Minimal reproducibility pack

Provide long-form fit-costs $(t, H, \varepsilon, \hat{C})$; capacity K; and a small script that computes SI and flags sustained crossings. (See companion repo/appendix for the SI detector and plotting scripts.)

4 Proxy dynamics and signals

Horizons manifest as coordinated shifts across proxies.

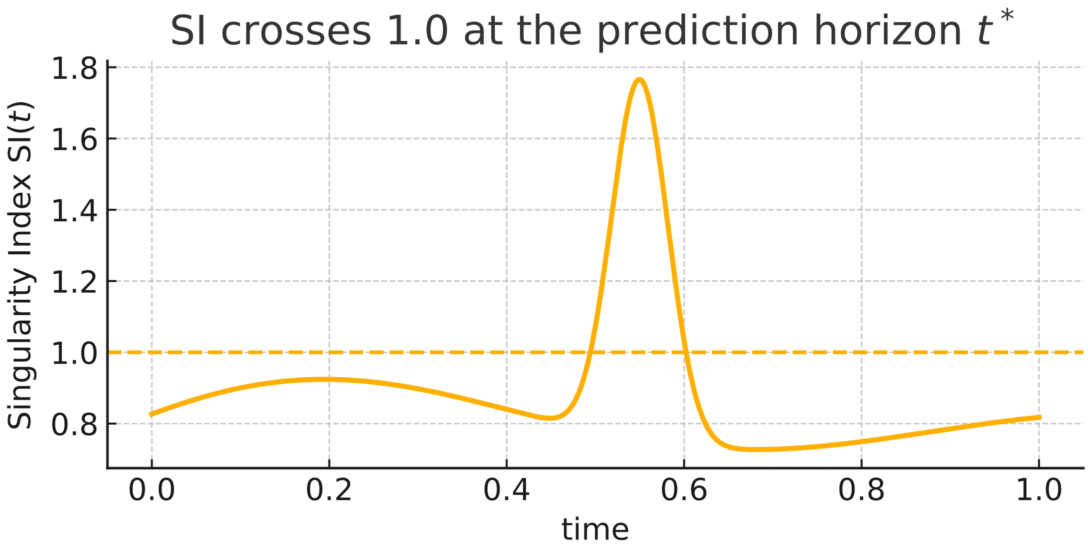

Figure 2: Singularity Index over time; horizon at sustained SI ≥ 1.

Figure 3: Flow: pipeline $\rightarrow$ cost $\rightarrow$ SI $\rightarrow$ detection $\rightarrow$ dashboards/interventions.

Label	**Operational criteria (suggested thresholds)**
Singularity (prediction horizon)	SI ≥ 1 sustained for W windows (default $W=5$ weekly) *and* dispersion z-score ≥ 2 *and* error-floor relative increase $\geq 20\%$ *and* half-life drop $\geq 40\%$ *and* churn spike $\geq 3\times$ baseline.
Turbulence/transition	Temporary SI ≥ 1 but fails proxy corroboration or lacks sustain; treat as elevated risk, not a horizon.

Table 1: When to say "singularity" vs "turbulence". Tune thresholds per domain.

Dispersion: ensemble forecast variance spikes near horizons. **Error floor:** the best achievable loss rises until new abstractions reduce task complexity. **Half-life:** state-of-the-art decays faster (shorter half-life). **Churn:** concept dictionaries refactor (merges/splits). **Compression stress:** MDL pressure increases. **Semantic FPS:** throughput dips under overload. **Consolidation deficit:** novelty outruns consolidation.

5 Sensitivity and design choices

Tolerance ε. Tighter accuracy induces earlier horizons (higher SI).

Capacity K. Increasing capacity delays the horizon.

Detector choices. CUSUM vs BOCPD trade detection delay and false alarms; require sustained crossings plus proxy corroboration.

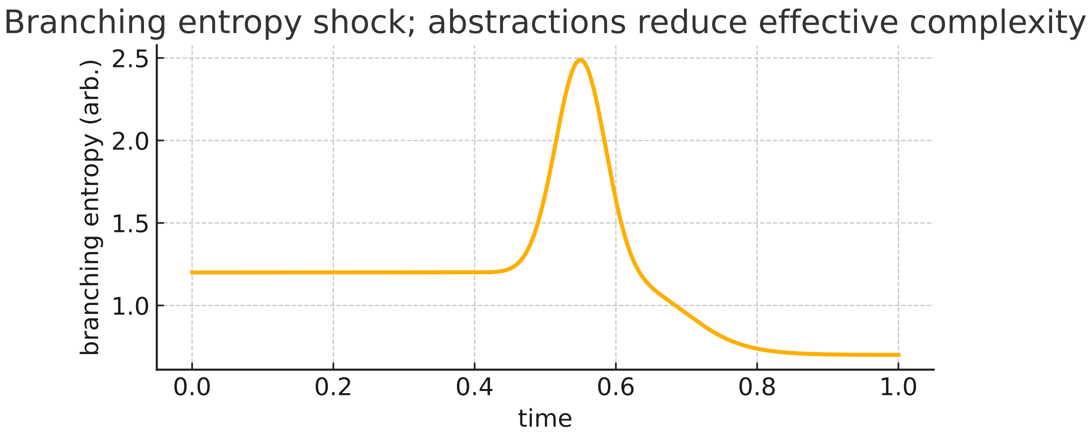

Figure 4: Branching entropy shock; abstractions restore compressibility.

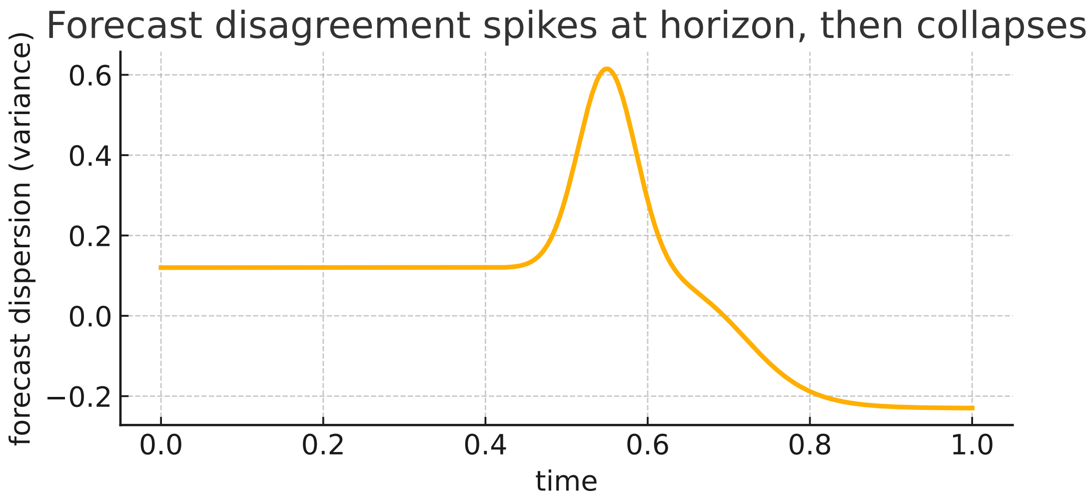

Figure 5: Forecast dispersion spikes at the horizon.

6 Case-study sketch: Internet 1992–2000

A widely-cited period of rapid structural change provides a concrete testbed.

Data plan. AS-graph growth and degree distributions; DNS zone counts; web crawl size; package/dependency growth; platform/API launch cadence; volatility in related markets. Align to weekly or monthly bins.

Protocol. Compute $\widehat{\mathrm{SI}}(t, H, \varepsilon)$ from fit-cost curves; detect sustained crossings; corroborate via dispersion, error floor, half-life, churn; estimate recovery when proxies stabilize and $\mathrm{SI} < 1$.

7 Discussion and implications

Why this reframing helps. It grounds "singularity" in agent-relative predictability, enabling measurement, monitoring, and governance interventions.

Phaneron mapping. Horizons mark phases where the meaning substrate lacks compressive motifs; abstraction discovery—the creation or recognition of higher-order patterns—reduces L

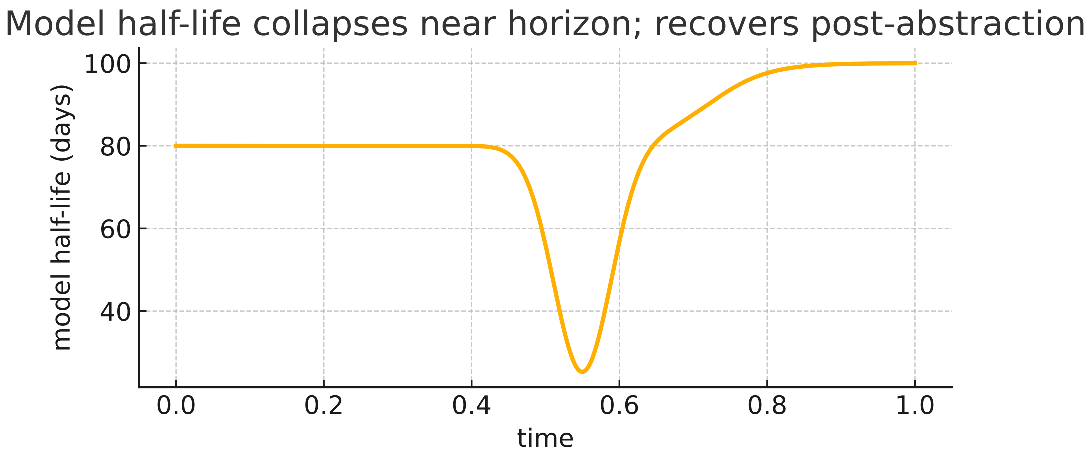

Figure 6: Model half-life collapses then recovers post-abstraction.

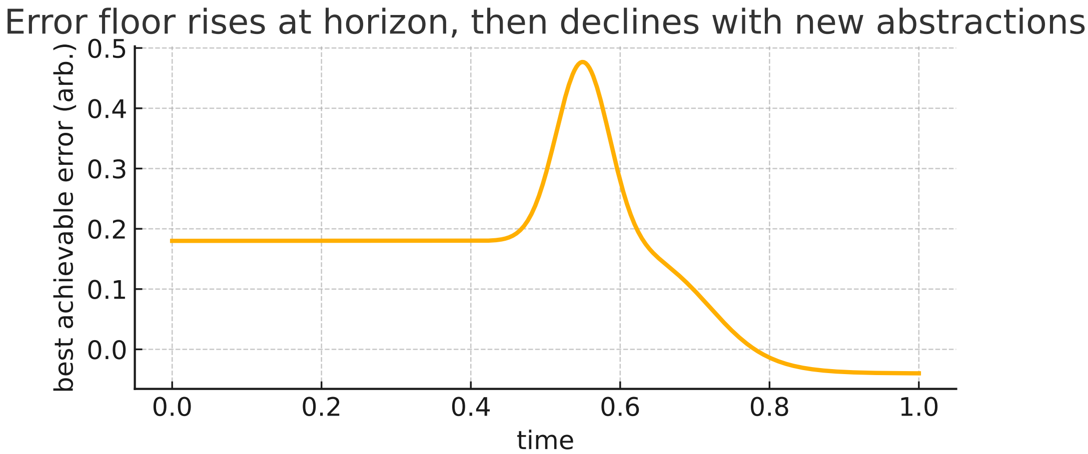

Figure 7: Error floor rises at the horizon, then declines.

and restores throughput.

Policy. Shorten turbulence windows by (i) accelerating abstraction discovery (standards, ontologies, education), (ii) raising effective K (tooling, compute, collaboration), (iii) monitoring SI and proxies, (iv) damping reflexive feedback loops.

8 Limitations and future work

Estimating C and K is approximate; proxies can be confounded; reflexivity can shift dynamics; thresholds are domain-specific. Future work: multi-agent/collective horizons, cross-domain calibration, and full historical reconstructions.

9 Conclusion

Singularities are predictability horizons. They appear when novelty outruns consolidation and recede when compressive abstractions and capacity catch up. With SI, proxy metrics, and simple detectors, the phenomenon becomes operational: measurable, monitorable, and manageable.

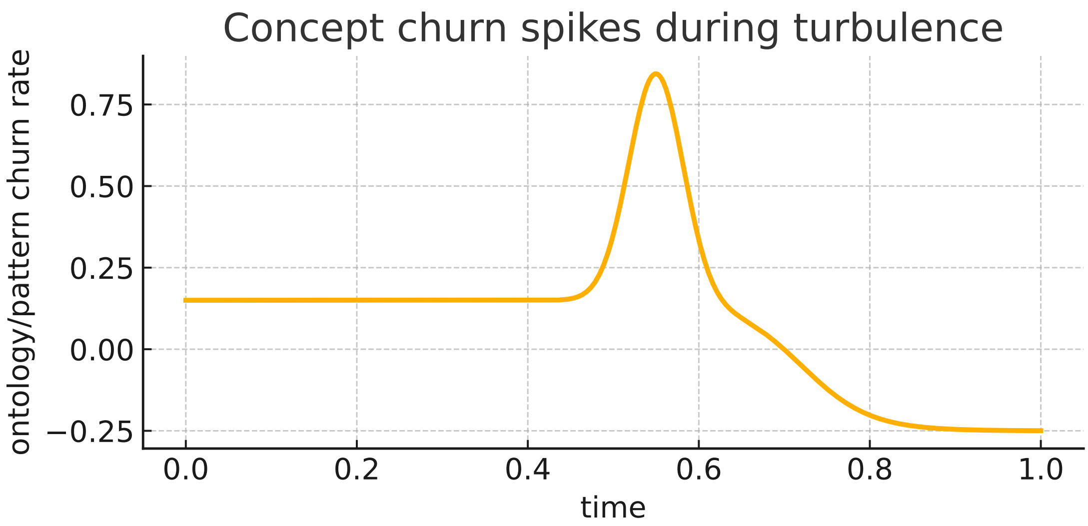

Figure 8: Ontology churn spikes during turbulence.

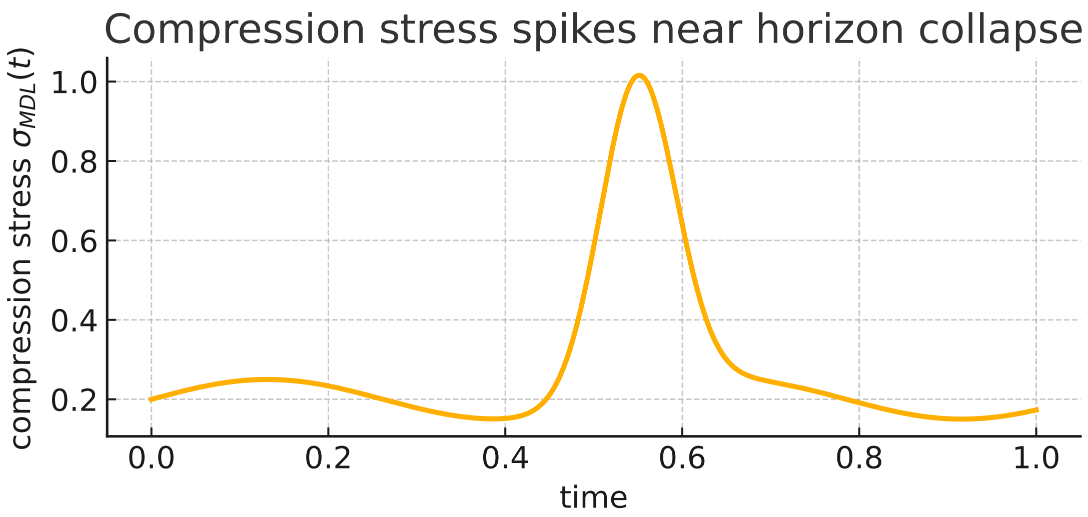

Figure 9: Compression stress indicates missing abstractions.

10 Stagewise Reflection and Singularities

Reflection parity is not a fixed point but a *stagewise* target. Let W_t be the micro-world, $\pi_{B,G}(t)$ the task-indexed quotient under resource bound B and goals G, and P_t the current Phaneron.

- **Stage k:** an interval $[t_k, t_{k+1})$ where there exists a homomorphism $h_k : P_t \to \pi_{B,G}(t)$ with task error $\leq \varepsilon(B)$ and P_t is MDL-minimal under the equilibrium objective.
- **Singularity at t_{k+1}:** the smallest time where no sequence of local refinements of $P_{t_{k+1}^-}$ can keep task error $\leq \varepsilon(B)$ without (i) raising capacity B, (ii) narrowing G, or (iii) introducing new invariants (a partition re-factor). Equivalently, the optimal partition changes topology/cardinality:

$$\mathcal{P}(B^-, G) \ncong \mathcal{P}(B^+, G) \quad \text{or} \quad |\mathcal{P}(B^-, G)| \neq |\mathcal{P}(B^+, G)|.$$

Predictability horizon. The horizon H at state (P_t, B, G) is the largest τ such that all task

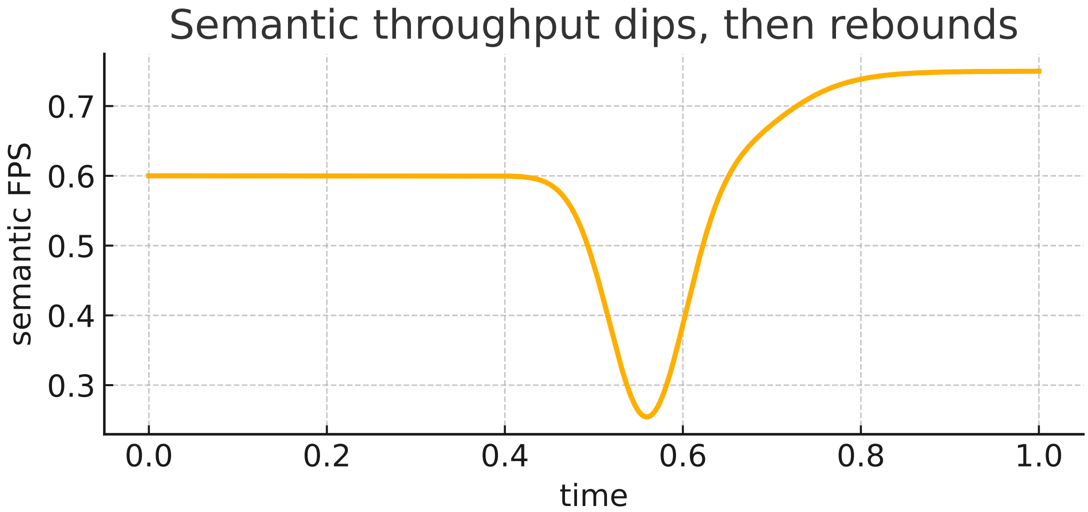

Figure 10: Semantic throughput dips, then rebounds.

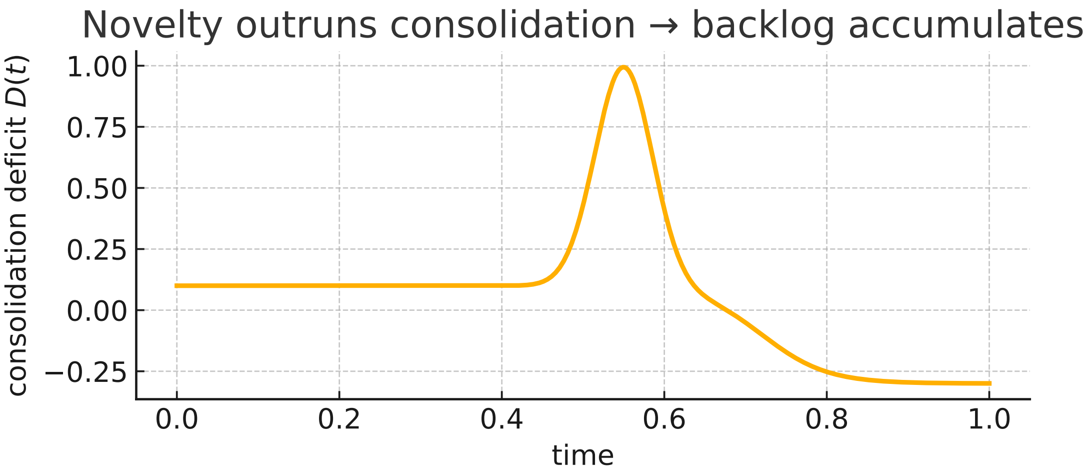

Figure 11: Novelty outruns consolidation until compressive patterns are found.

queries within $[t, t+\tau]$ admit bounded regret under the current partition; beyond H, any reliable forecast requires a partition transition (capacity increase or new invariants).

Precursors and a practical score. As a singularity approaches, we typically observe: (i) rising conflict curvature despite consolidation, (ii) increasing residual variance and autocorrelation in forecast errors, (iii) accelerated split/merge churn and codebook drift, (iv) longer/variable MES and message-size spikes in multi-agent settings, and (v) a stall in reflection-distance improvement. A simple trigger uses a weighted score $S(t)$ over these signals and initiates a controlled re-factor when $S(t) > \tau$.

Consequences. Intelligence growth is piecewise: long plateaus of reflection parity punctuated by singularities when tasks/evidence demand new invariants. This explains "unknown unknowns" pre-transition, collective communication cliffs when teams align a finer partition, and subjective time shifts when cognitive debt is reduced across a transition.

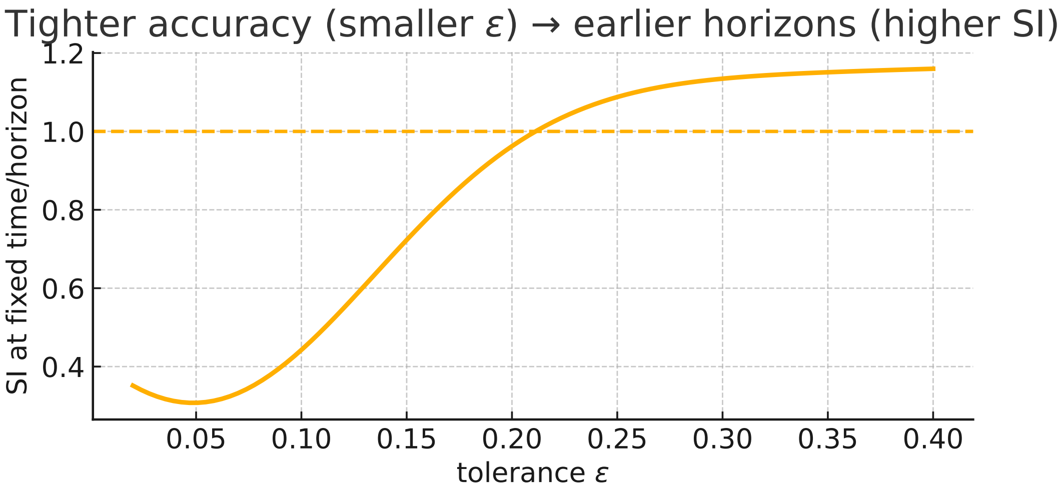

Figure 12: Tighter accuracy (smaller ε) yields earlier horizons.

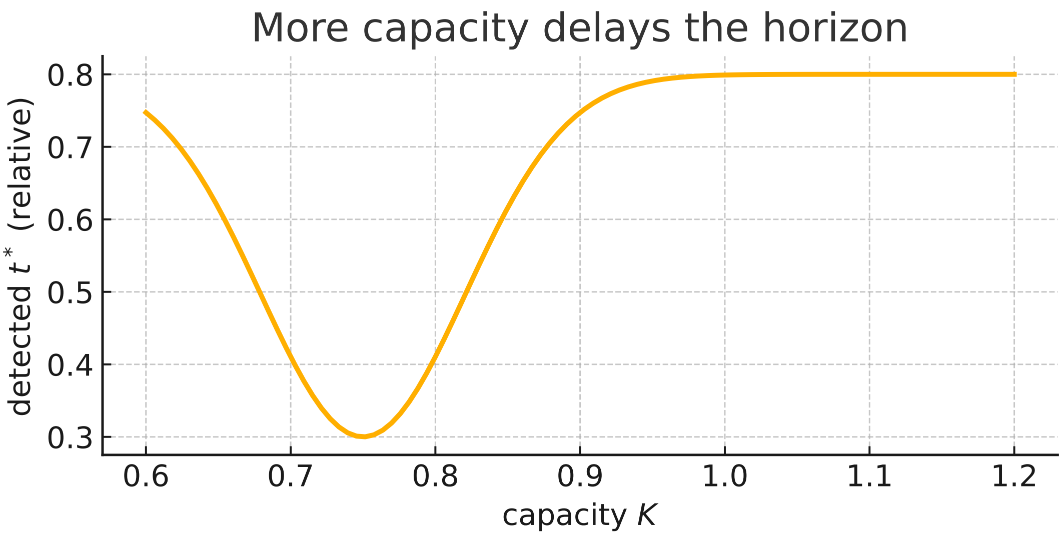

Figure 13: More capacity K delays t^*.

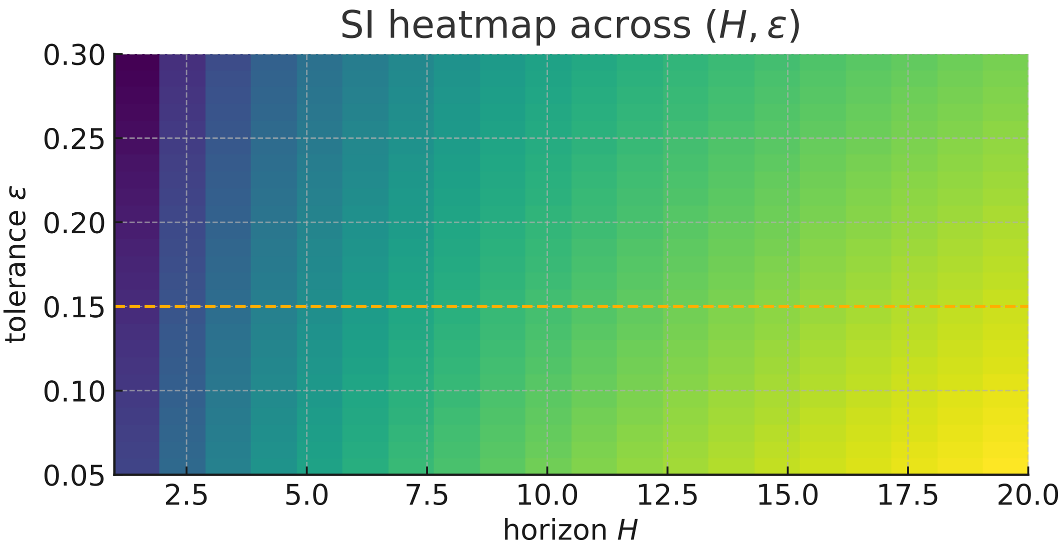

Figure 14: SI heatmap across (H, ε) at a fixed time slice.

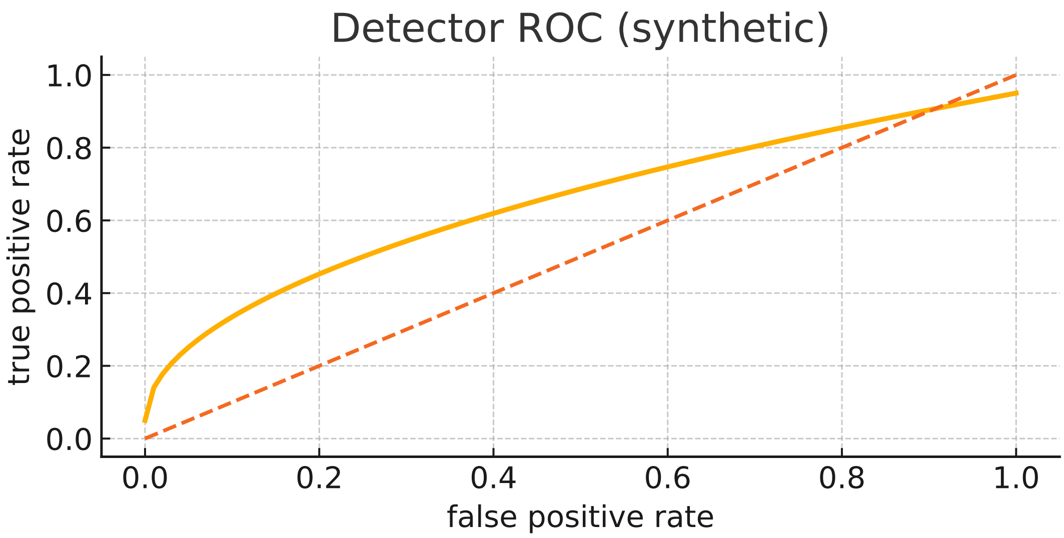

Figure 15: Detector ROC (synthetic) for sustained-crossing alarms.

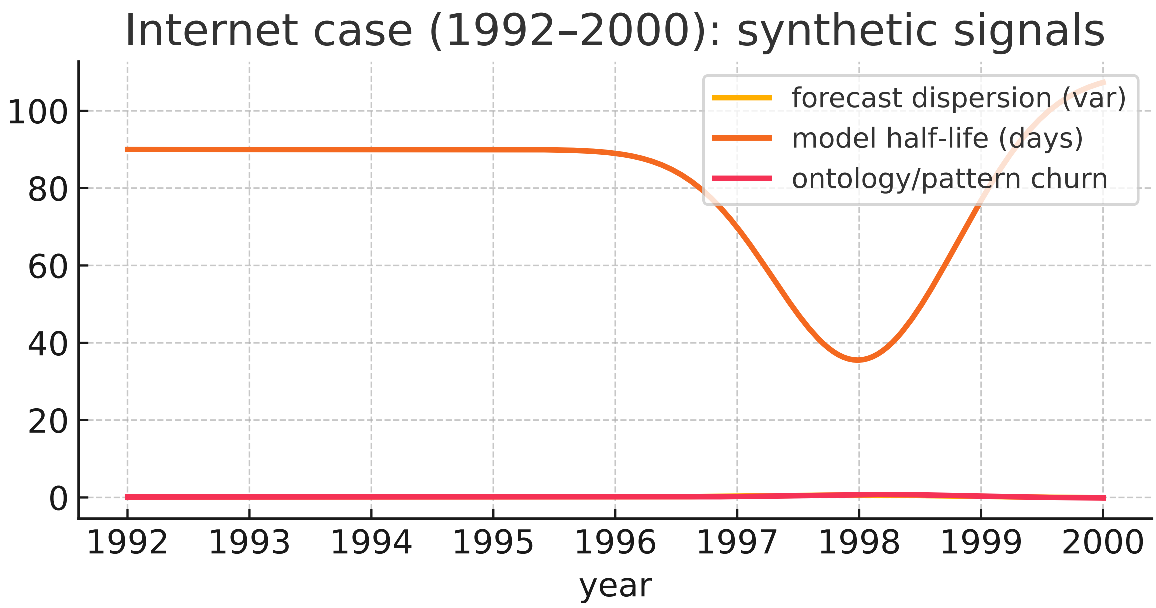

Figure 16: Internet case: synthetic proxy signals (illustrative shapes).