

Tensor-Geometric Control and Reconstruction

Next-Generation Solutions for High-Dimensional Systems



Complex Systems Are Drowning in Flat Telemetry

Modern cyber-physical systems are too high-dimensional to be managed by scalar counters and independent alerts.

Correlated anomalies hide in the blind spots of disjointed monitoring.

Independent asset health fails to capture system-level dependencies.

Risk is treated as a flat metric, not a compounding topological threat.

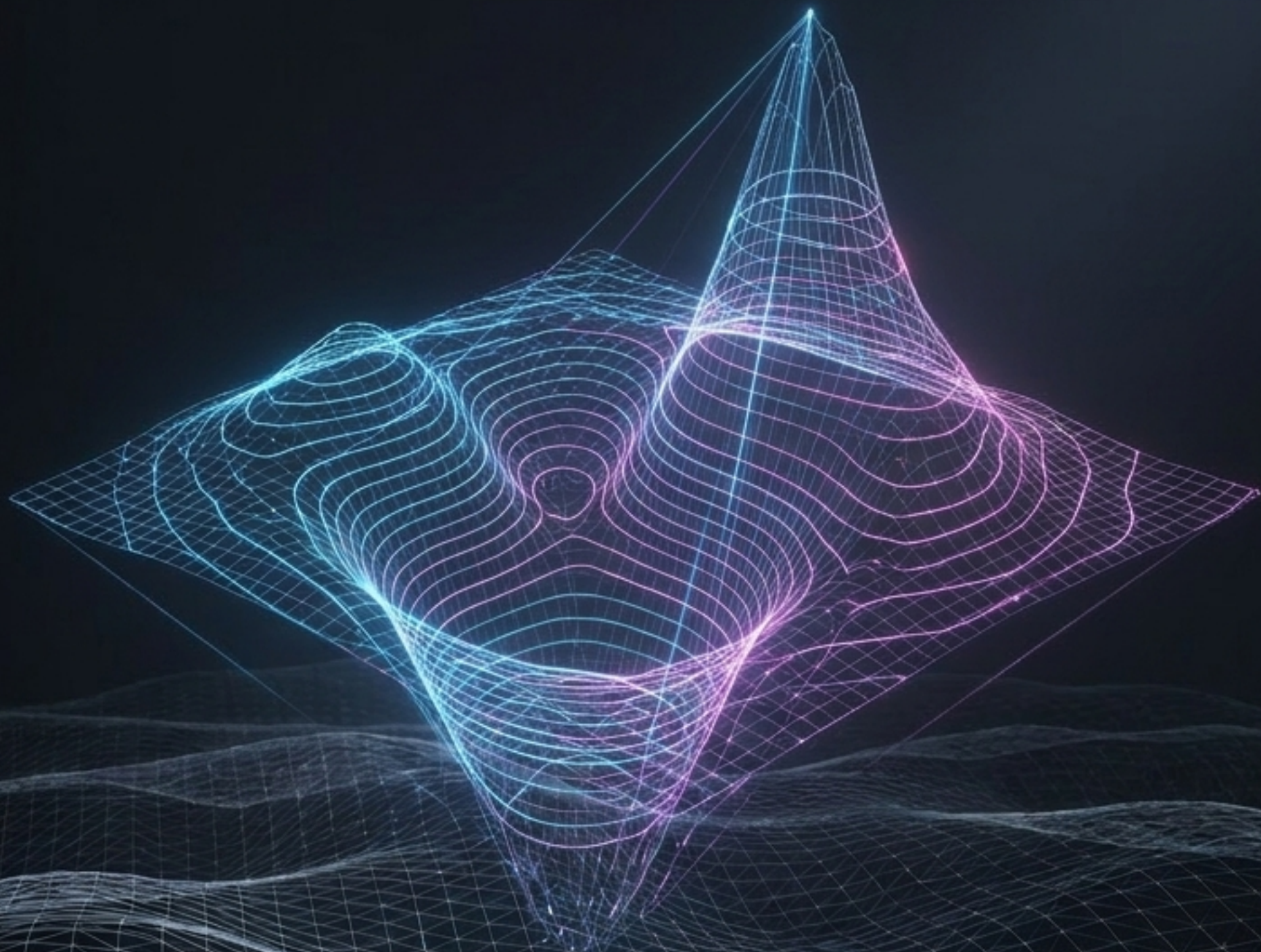


Transforming Noise into Navigable Geometry

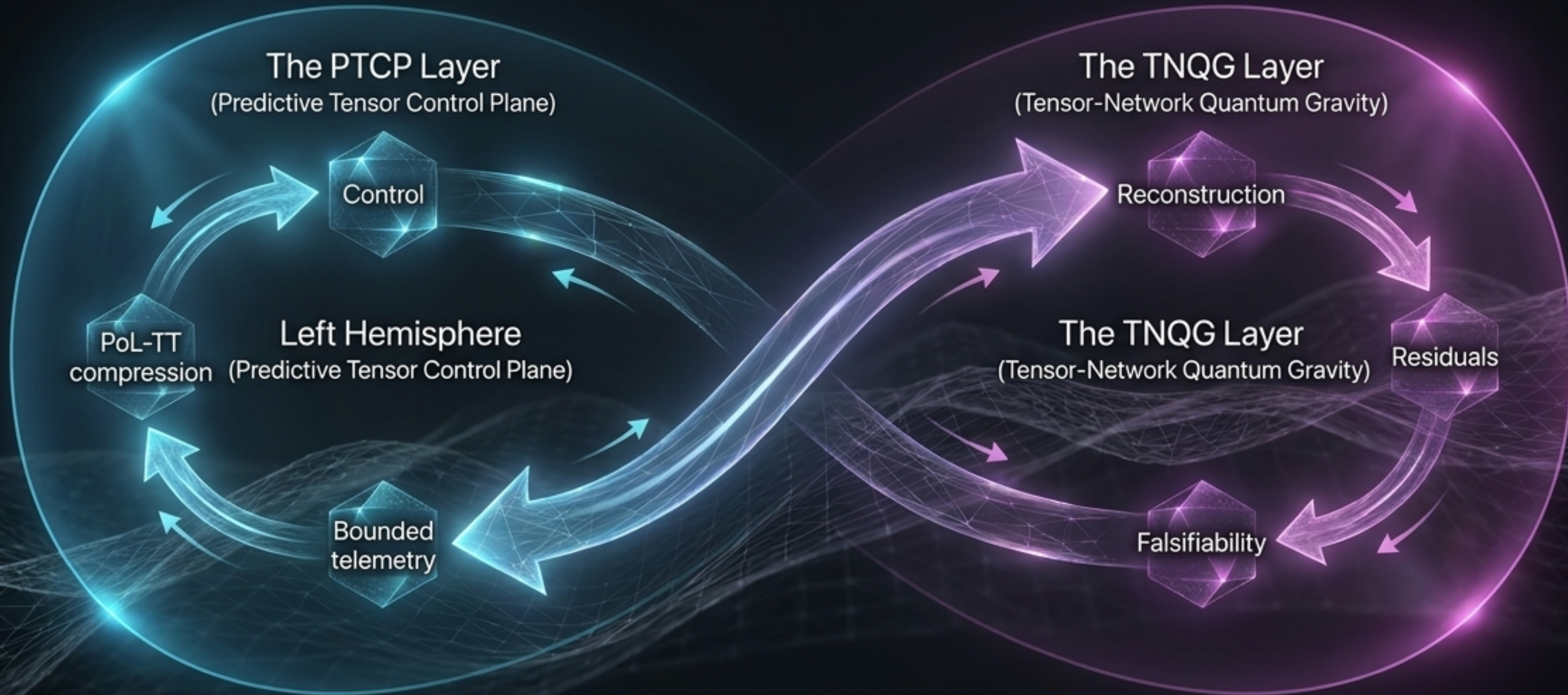
What if we could see the operational shape of the system? By mapping multidimensional data to geometry, we reveal the hidden topological structure of complex dependencies.

Complex dependencies have an operational geometry.

Tensor-level compression turns overwhelming noise into an actionable, spatial landscape.



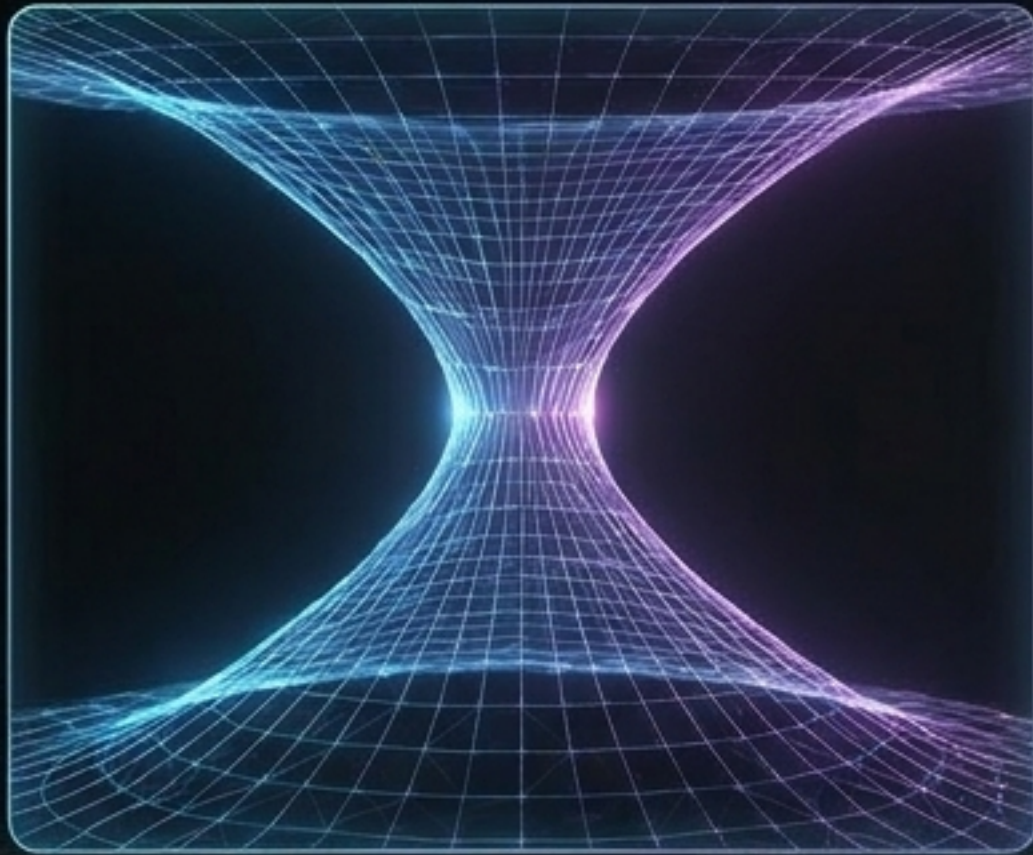
A Dual-Engine Framework for High-Dimensional Control



The integration of PTCP and TNQG creates a unified operating model. PTCP provides the bounded action and telemetry; TNQG provides the falsifiability and geometric reconstruction.

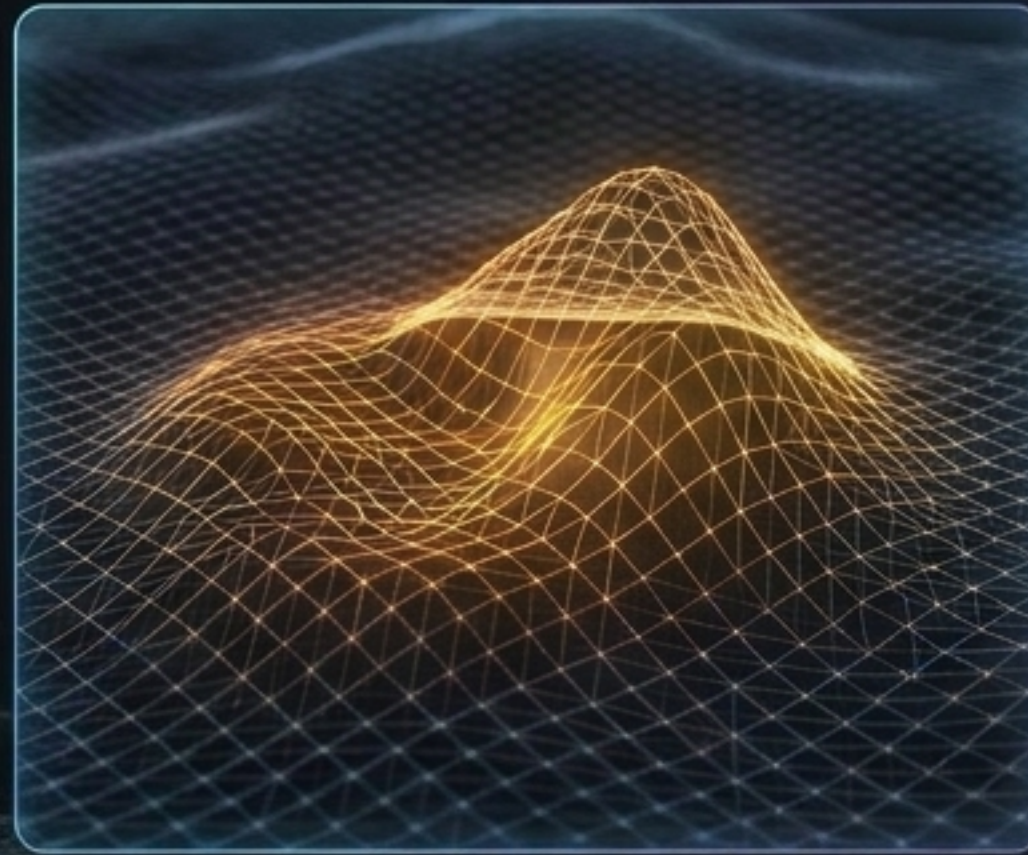
Mapping Network Behavior to Physical Topography

Bottlenecks as "Cuts"



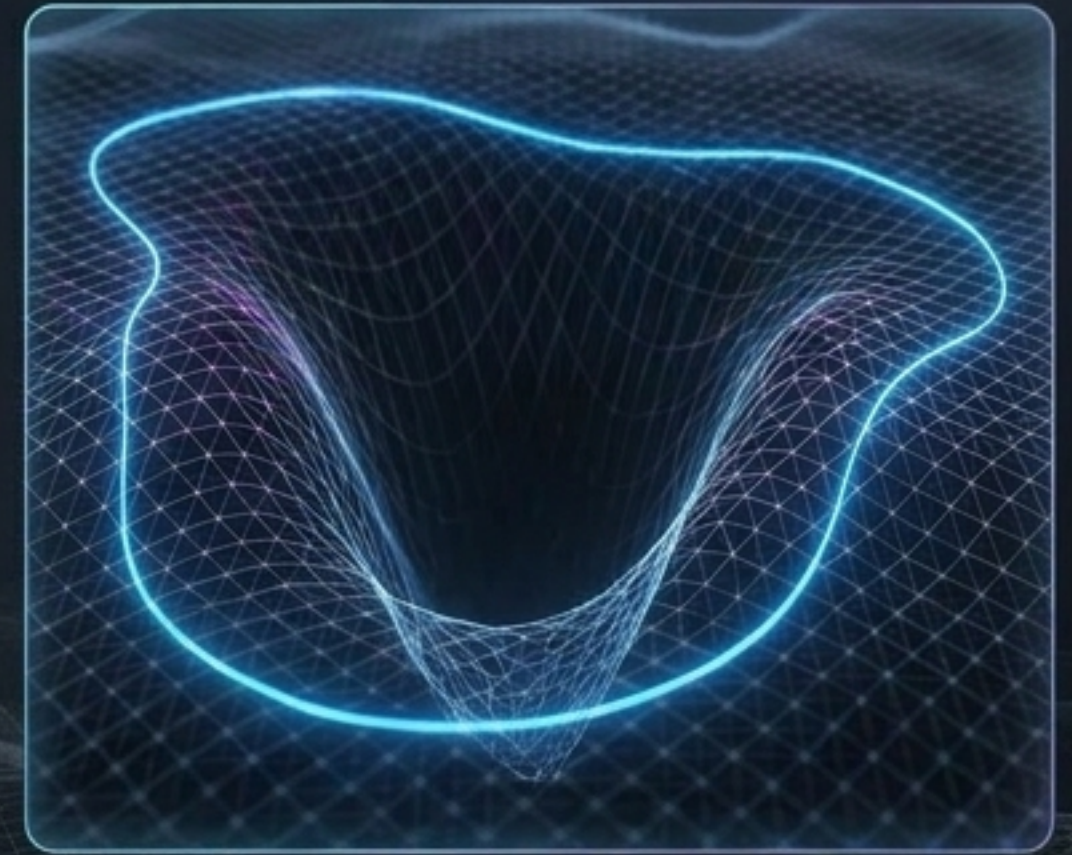
Network capacity and physical thresholds manifest as measurable bottlenecks in the topological structure.

Anomalies as "Curvature"



Coordinated attacks or systemic stress warp the expected shape of the operational pattern-of-life.

Risk as "Distance"

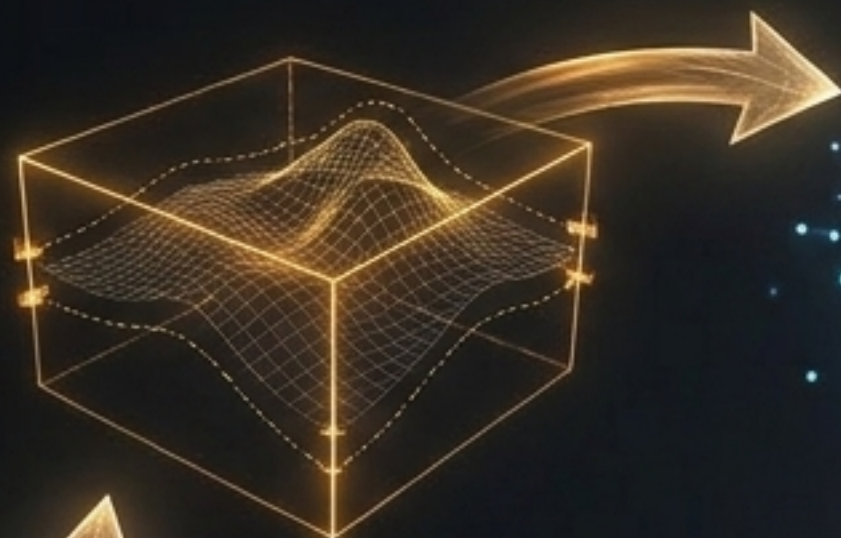


Risky, unverified, or contested routes literally stretch further apart, forcing the system toward safe paths of least resistance.

The Tensor-Geometric Processing Cycle

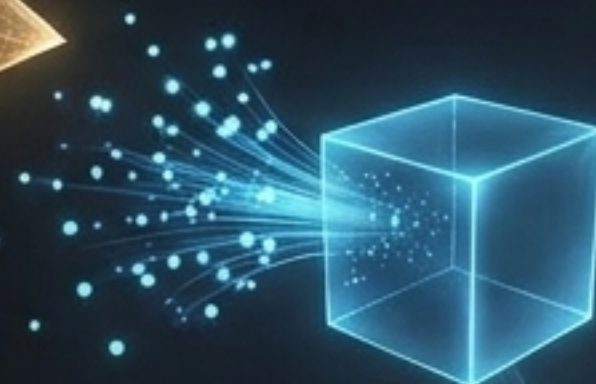
Validate (Residuals & Safety Gates)

Force every claim through prediction residuals, safety envelopes, and domain constraint tests.



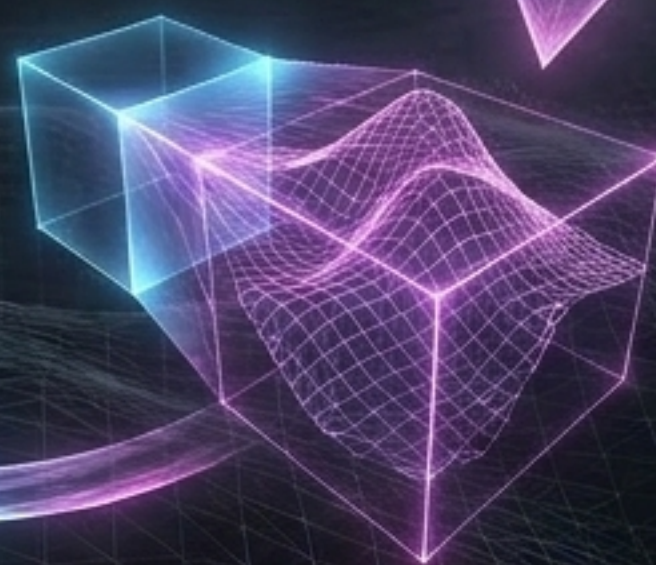
Compress (Telemetry to Tensor)

High-dimensional state is compressed into a bounded Pattern-of-Life Tensor Train (PoL-TT) density model.



Reconstruct (Tensor to Geometry)

The model maps capacities to lengths, cuts, and curvatures using the TNQG dictionary.



Predict & Route (Risk-Aware Action)

Generate scenarios with transition models to select paths minimizing expected cost plus tail-risk penalties.



Standard Pipelines vs. Tensor-Geometric Architectures

Scalar Telemetry Pipelines

Tensor-Geometric Architecture

State Representation

Independent counters and flat vector embeddings.

Low-rank **Pattern-of-Life** tensor density.

Routing Optimization

Mean-path cost and Equal-Cost Multi-Path (ECMP).

Risk-aware geodesic routing (Expected cost + Conditional Value-at-Risk).

Anomaly Detection

Isolated SIEM alerts and disjointed threshold breaches.

Topology-native defect detectors (D_{topo}) combining likelihood, curvature, and cut shifts.

Validation

Unquantified blind spots and black-box confidence scores.

Physics-inspired falsifiability; explicit residuals quantify the delta between model and reality.

Next-Gen Defense: Mission-Aware Routing in Contested Networks

Fusing zero-trust telemetry across identity, device, and topology to maintain mission continuity in degraded environments.



Deception-Resistant Anomaly Detection:

D_{topo} localizes regions where anomalies, curvature changes, and cut changes agree, ignoring spoofed scalar noise.



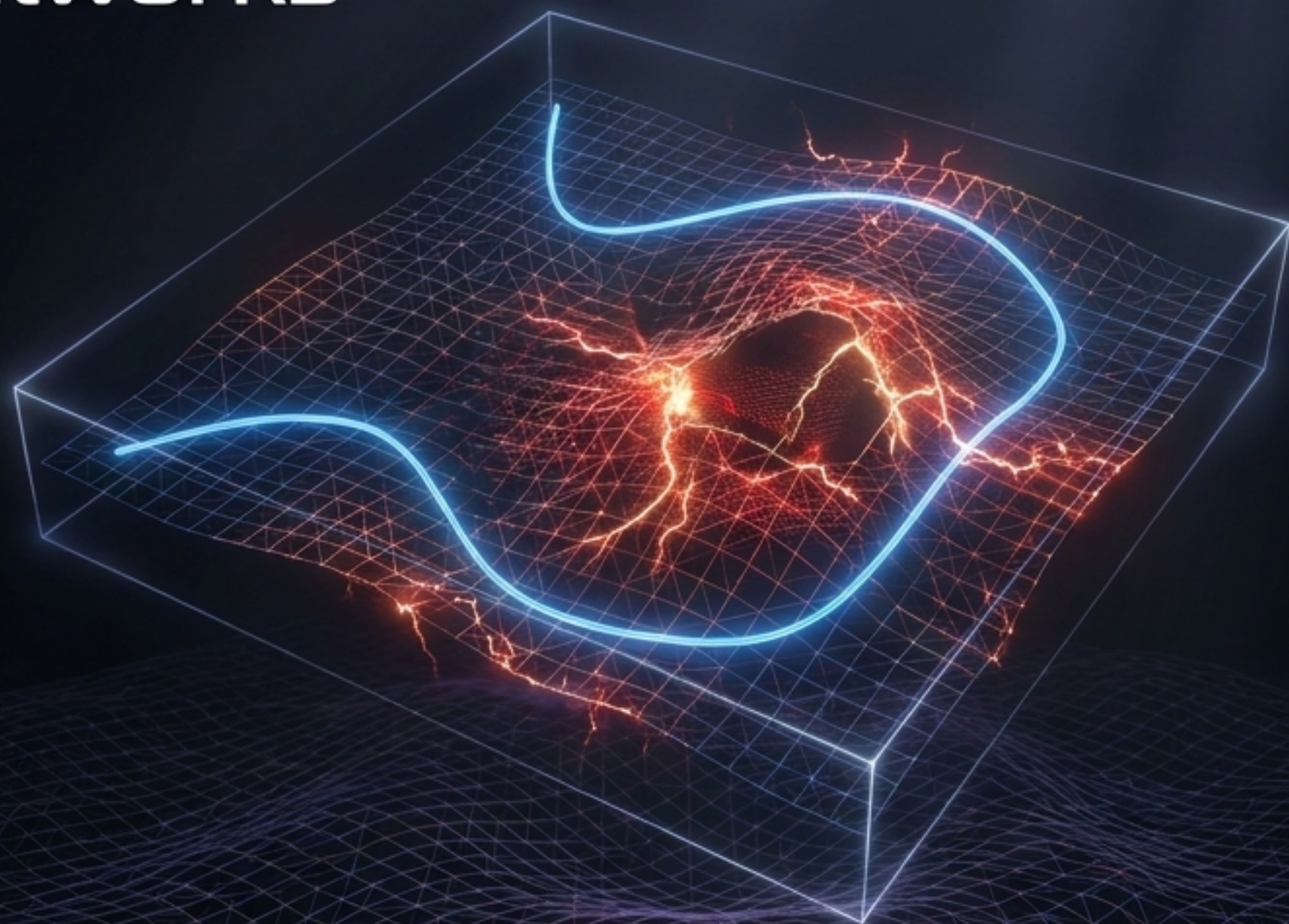
Tail-Risk Resilience:

Routing automatically isolates compromised regions without requiring autonomous, mission-breaking quarantine.



DODIN Application:

Dynamic trust paths natively support zero-trust execution roadmaps.



Securing Cyber-Physical Resilience and OT Processes

Modeling industrial control systems not as isolated assets, but as coupled operational geometries combining process state, safety constraints, and network trust.



Predictive Maintenance:

Uncover system-level dependencies. A machine may be healthy in isolation but topologically fragile in the broader workflow.



OT/ICS Security:

Avoid autonomous IT quarantines that interrupt physical control; apply safety-preserving process responses.



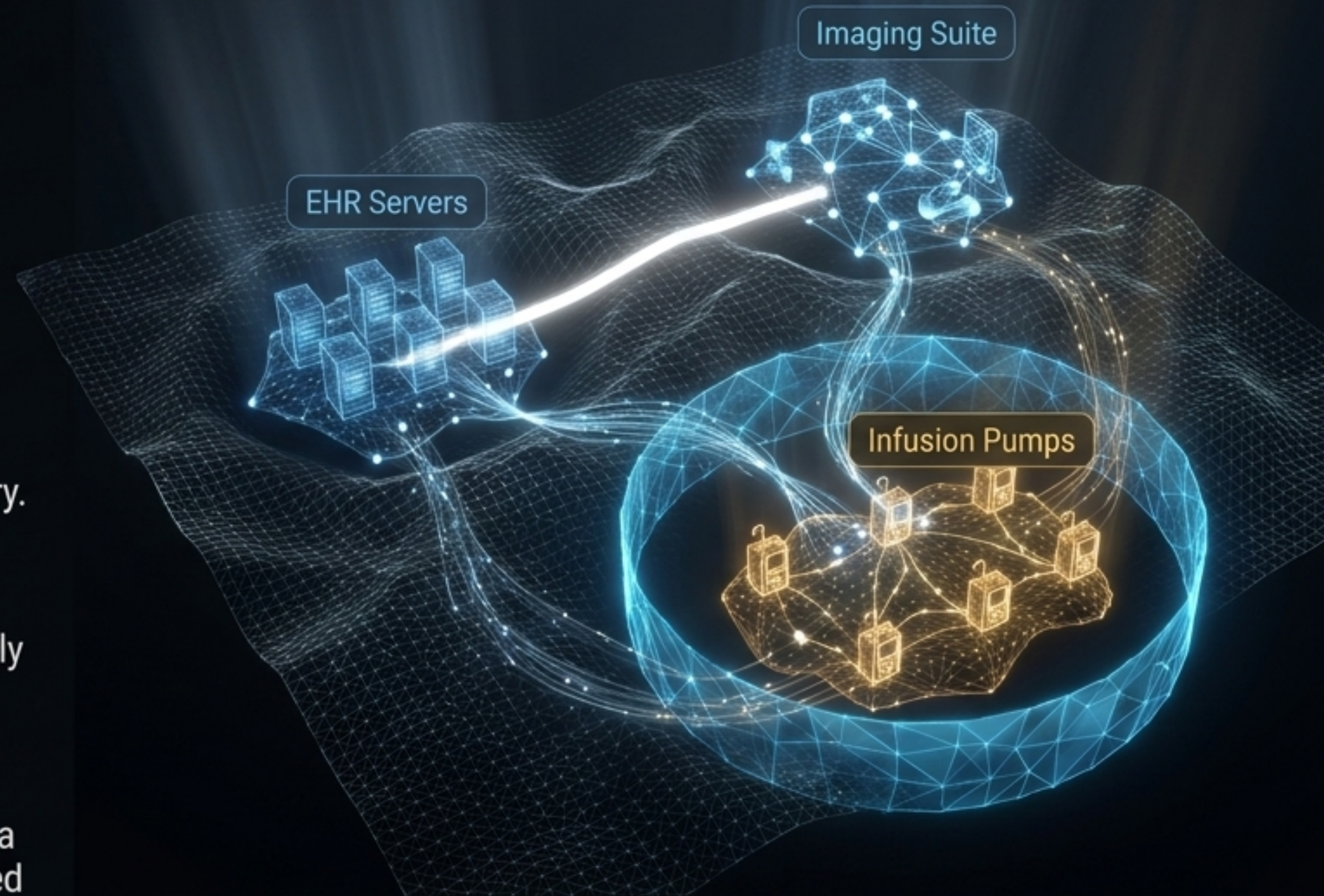
Yield Protection:

Monitor complex dependencies in semiconductor fabs and energy grids to prevent cascading yield or capacity losses.



Protecting Clinical Continuity and Medical Device Fleets

Securing federated clinical telemetry and ensuring hospital operational resilience without interrupting patient care pathways.



Device Fleet Monitoring: Transform unprioritized vulnerabilities into a trust-weighted device graph, identifying true risk via anomalous subnet geometry.



Multimodal Telemetry Compression: Manage highly dimensional streams (vitals, waveforms, logs) to track the stability of hospital wards.



Strict Patient Safety Boundary: TGCR operates as a resilience and security overlay, explicitly constrained by FDA/HHS-aligned patient safety protocols.

Orchestrating Exascale Workflows and Quantum Sensors

Applying tensor-geometric observability to manage bursty data flows, distributed sensor calibration, and high-dimensional physics digital twins.



Scientific Cyberinfrastructure:

Dynamic routing of large experiment datasets and predictive scheduling across compute centers.



Residual-Guided Digital Twins:

For climate, plasma, and materials simulations, residuals automatically direct computational attention to where the model is failing.



Quantum Sensing Arrays:

Reconstruct spatial field geometry from distributed measurements, identifying sensor drift or loss dynamically.



Universal Geometric Primitives, Domain-Specific Outcomes



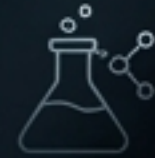
Defense



Industrial



Medical



Scientific

**Primary
Pain Point**

Context overload & contested routing.

Coupled IT/OT failures & yield loss.

Care continuity under cyber stress.

Massive data movement & sensor drift.

**The TGCR
Mechanism**

CVaR geodesics & PoL-TT trust.

Tensor cyber-physical twin & D_topo defects.

D_topo service regions & capacity geometry.

Risk-aware routes & TNQG residual maps.

**Validation
Evidence**

Tail latency, mission availability.

Reliability, safety trips, maintenance records.

False isolation impact, FDA alignment.

p99 transfer time, measurement accuracy.

Constraining Power with Inflexible Policy Envelopes

Powerful predictive control requires unbreakable leashes. Actuation only occurs within strictly defined, mathematically guaranteed boundaries.



Bounded Actuation:

The policy envelope encodes maximum rate of change, forbidden actions, and minimum availability requirements.



Blast-Radius Protection:

Strict constraints prevent autonomous models from executing cross-domain, mission-breaking quarantines.



Human-in-the-Loop:

Mandatory human approval thresholds scale with mission criticality and classification sensitivity.



Falsifiability Sourced from Mathematical Physics

If the geometry breaks, the system alerts operators. We do not hide black-box hallucinations; we explicitly quantify them using residual testing.



The Residual Delta:

Measuring the deviation between the model's geometric assumptions and ground-truth reality.



Falsifiability Culture:

No geometric claim is trusted unless it survives controlled perturbations, coarse-graining, and held-out residual tests.

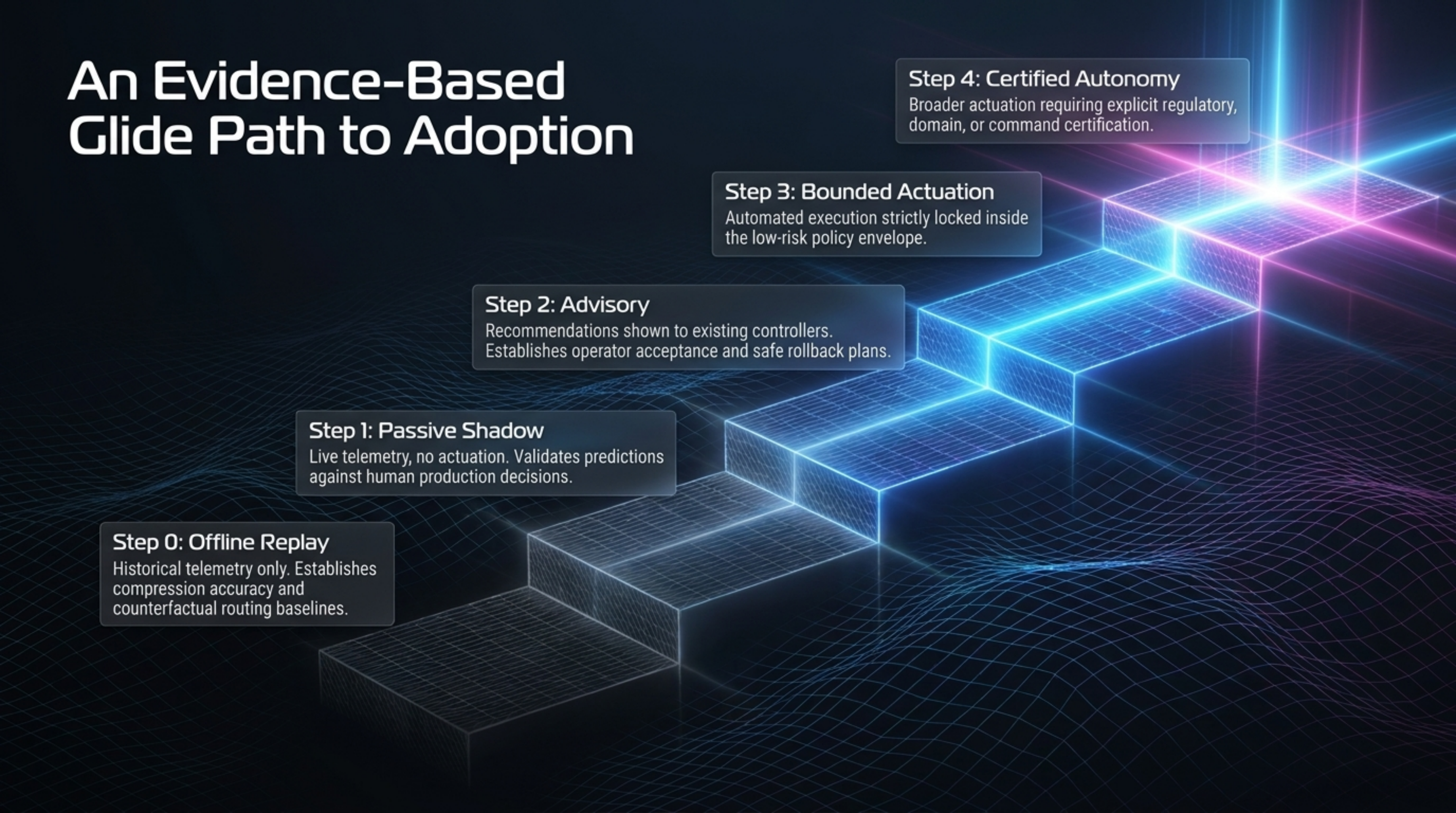


Operator Trust:

A recommendation always states which assumptions hold, which feature correlations produced the geometry, and whether residuals have grown.



An Evidence-Based Glide Path to Adoption



Step 0: Offline Replay

Historical telemetry only. Establishes compression accuracy and counterfactual routing baselines.

Step 1: Passive Shadow

Live telemetry, no actuation. Validates predictions against human production decisions.

Step 2: Advisory

Recommendations shown to existing controllers. Establishes operator acceptance and safe rollback plans.

Step 3: Bounded Actuation

Automated execution strictly locked inside the low-risk policy envelope.

Step 4: Certified Autonomy

Broader actuation requiring explicit regulatory, domain, or command certification.

Unmatched Operational Control Over System Complexity

The Scientific Horizon

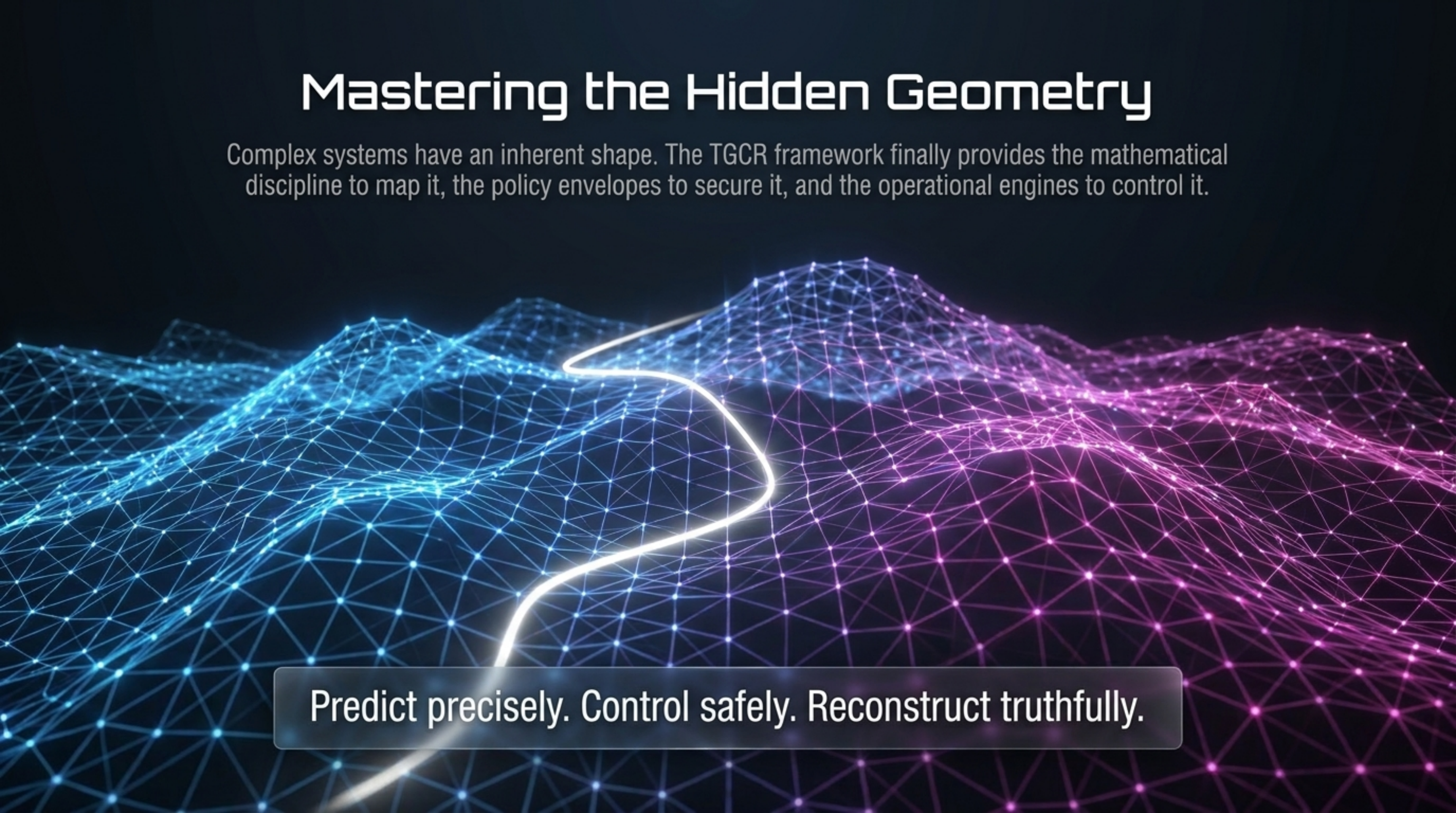
- Testing deep questions in tensor-network quantum gravity.
- Falsifiable reconstruction programs for mathematical physics.

The Near-Term Reality

- **NOT** a claim of physical spacetime engineering or autonomous clinical diagnosis.
- **IS** a highly actionable, dual-use analytics platform delivering unmatched telemetry compression, tail-risk routing, and anomaly localization today.

Mastering the Hidden Geometry

Complex systems have an inherent shape. The TGCR framework finally provides the mathematical discipline to map it, the policy envelopes to secure it, and the operational engines to control it.



Predict precisely. Control safely. Reconstruct truthfully.