

CONTROLLED ENGINEERING PUBLICATION

8Sphere

Systems Architecture and Engineering Design Package

Professional Compact PDF Edition

Master System Design Specification + Ten Supporting Engineering Documents

SOPHIA

CHARLOTTE

LANDON

Document Set: 8S-ENG-PKG-002 | Version: 2.0.0 | Status: Engineering design baseline

Designed from the 8Sphere Relationships 1-100 laboratory program. This package supports research, simulation, monitoring, validation, and governed decision support. It does not independently authorize autonomous financial or operational action.

Publication Control and Reading Guide

This edition consolidates the complete 8Sphere engineering baseline into a compact, audit-ready publication. Typography, spacing, tables, figures, and section transitions have been rebuilt to remove unnecessary blank areas while retaining readable margins and formal document control.

Control item	Baseline
Document-set authority	SOPHIA: claims and action boundaries; CHARLOTTE: architecture and conformance; LANDON: controlled execution and evidence
Evidence basis	Relationships 1-100 laboratory program and controlled evidence files
Preserved exception	Relationship 91 remains a failed gate because the baseline false-alarm rate exceeded the frozen ceiling
Preserved limitation	Relationship 12 retains a run-level evidence-availability limitation
Claim boundary	Internal mathematical and synthetic consistency is not equivalent to external empirical or production validation
Intended audience	System owners, architects, engineers, researchers, validators, security teams, operators, auditors, and accountable decision authorities

Document Set

No.	Controlled document	Purpose
0	8Sphere System Design Specification	Master system design baseline integrating mathematics, architecture, data, security, validation, operations, governance, and traceability.
1	8Sphere System Requirements Specification	Normative functional, quality, security, governance, interface, data, and operational requirements.
2	8Sphere Software Architecture Document	Component boundaries, services, events, runtime flows, deployment topology, and technology constraints.
3	8Sphere Mathematical and Algorithmic Specification	Authoritative formulas, assumptions, tolerances, numerical methods, and executable pseudocode.
4	8Sphere Data and Evidence Specification	Data schemas, evidence lineage, provenance, versioning, retention, reproducibility, and audit controls.
5	8Sphere Interface and Observatory Design Specification	Observatory dashboards, workflows, alerts, controls, accessibility, and human-review patterns.
6	8Sphere Security and Threat Model	Assets, adversaries, attack surfaces, trust zones, mitigations, detection, and incident response.
7	8Sphere Verification and Validation Plan	Laboratory regressions, system verification, real-data validation, release gates, and independent review.
8	8Sphere Deployment and Operations Manual	Installation, configuration, monitoring, backup, recovery, upgrades, rollback, and troubleshooting.
9	8Sphere Governance and Model-Risk Framework	Claim classes, authority separation, model risk, approvals, exceptions, and ongoing oversight.
10	8Sphere Lab-to-System Traceability Matrix	Direct mapping from Relationships 1-100 to requirements, components, tests, controls, and evidence.

Identifier System

Prefix	Meaning	Prefix	Meaning
REQ-	System requirement	CMP-	Architectural component
API-	Synchronous interface	EVT-	Event contract
TST-	Verification or validation test	CTRL-	Governance or security control
EVD-	Evidence record or package	RSK-	Risk or threat record

Controlled-use notice. Every deployed implementation must retain visible claim classes, immutable evidence links, human authority at material action boundaries, and explicit records of failed, waived, degraded, or incomplete gates.

8Sphere System Design Specification

DOCUMENT 00

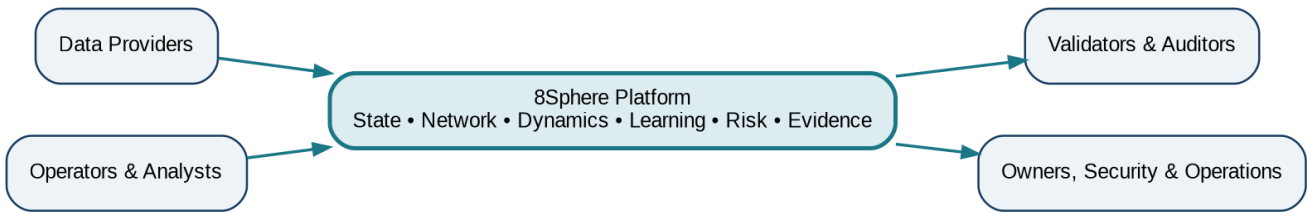
Master system design baseline integrating mathematics, architecture, data, security, validation, operations, governance, and traceability.

Document ID: 8S-SDS-001
Version: 1.0.0
Status: Engineering design baseline - not production authorization
Source: 8Sphere Relationships 1-100 laboratory evidence and professional expository note

Controlled-use notice. This document is an engineering design artifact. The laboratory program establishes internal mathematical and synthetic consistency under documented conditions. It does not independently establish real-world predictive performance or authorize automated financial or operational action.

1. Executive Summary

The 8Sphere platform converts the Relationships 1-100 laboratory program into a governable research, simulation, monitoring, and decision-support architecture. It combines a deterministic mathematical kernel, bounded five-coordinate state, normalized S3 fiber, signed and multiplex network analysis, nonlinear dynamics and control, statistical learning and calibration, risk and resilience, a Digital Twin, an operator Observatory, and an immutable Evidence Ledger.



8Sphere system context

Preserved limitations. Relationship 91 remains a failed baseline gate because its false-alarm rate exceeded the frozen ceiling. Relationship 12 retains a run-level evidence-availability limitation. Neither condition may be hidden by the aggregate pass count.

2. Purpose and Scope

The design supplies a common engineering baseline for researchers, developers, validators, operators, security personnel, auditors, and decision authorities. Domain deployments must define the five coordinate meanings, fiber semantics, graph construction, target event, alert costs, and action authority before empirical use.

2.1 Objectives

- Implement the 8Sphere mathematics with explicit tolerances and conditioning controls.
- Convert every laboratory relationship into a requirement, component consequence, regression test, and evidence obligation.
- Keep observed, derived, synthetic, predictive, advisory, and action states distinguishable.
- Make every material result reproducible and evidence-linked.
- Support offline and air-gapped operation.
- Preserve failures, uncertainty, overrides, and exceptions.

3. Mathematical Foundation

The canonical state is $X_t=(b_t,q_t,G_t,\theta_t,u_t,E_t)$ $X_t=(b_t,q_t,G_t,\theta_t,u_t,E_t)$, where $b_t\in[-1,1]$ $b_t\in[-1,1]^5$ is the bounded base, $q_t\in S^3$ $q_t\in S^3$ is the normalized fiber, G_t G_t is the coupling graph, θ_t θ_t is the model and parameter state, u_t u_t is a candidate intervention, and E_t E_t is the evidence state.

The hard capacity radius is

$$r(b)=\prod_{i=1}^51-b_i^2,r(b)=\prod_{i=1}^5\sqrt{1-b_i^2},$$

and logarithmic damage is

$$D(b)=-\log r(b)=-12\sum_{i=1}^5\log(1-b_i^2).D(b)=-\log r(b)=-\frac{12}{5}\sum_{i=1}^5\log(1-b_i^2).$$

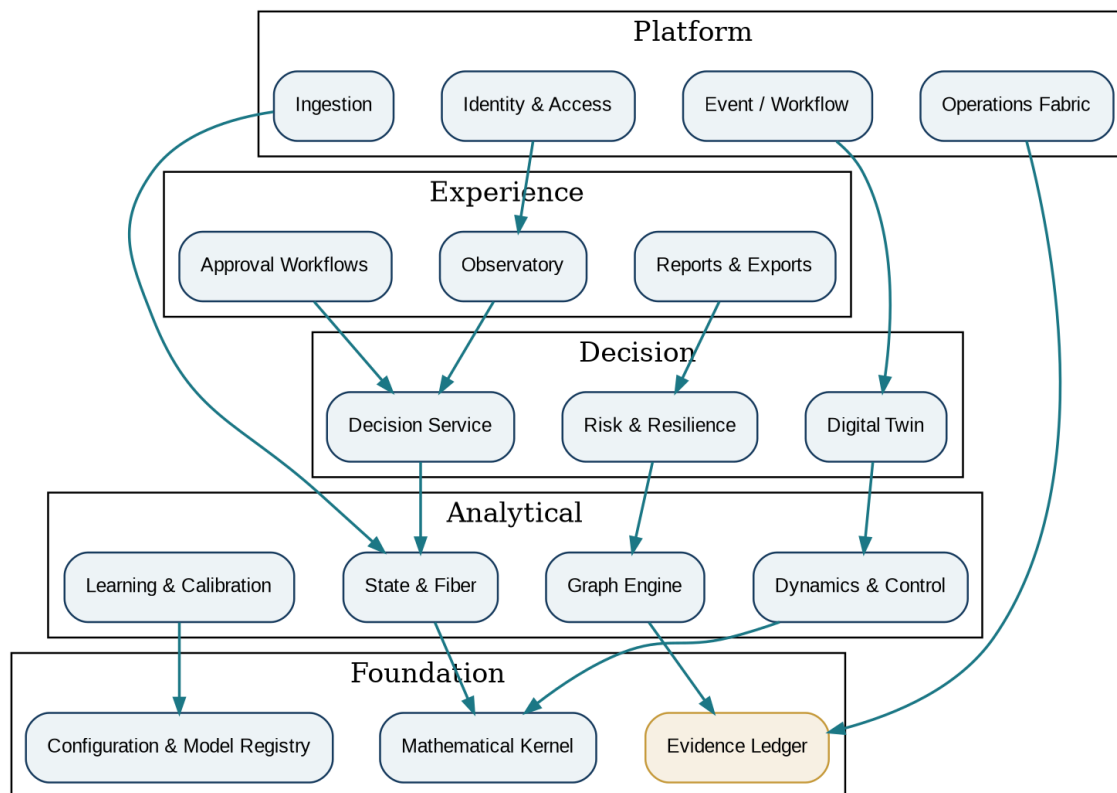
The design also implements differential sensitivity, weighted and softened radii, S3 geometry, transport and holonomy, projection and information measures, graph spectra, cascade dynamics, control, learning, uncertainty, tail risk, robustness, causal validation, and governance gates.

4. Design Principles

Principle	Engineering consequence
Evidence before assertion	No result may be promoted beyond its claim class without the required evidence and approval.

Principle	Engineering consequence
Deterministic core and explicit uncertainty	Analytic functions are deterministic; estimates and predictions retain uncertainty and provenance.
Separation of authorities	Claim governance, conformance, execution, validation, security, operations, and approval remain distinct.
Human control at material boundaries	High-consequence actions require explicit policy and accountable authority.
Offline-capable portability	Core operation has no mandatory public-network dependency.
Failure visibility	Failed tests, degraded data, overrides, and incomplete evidence remain visible.

5. Logical Architecture

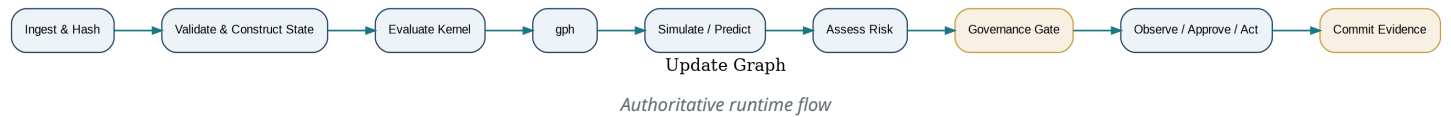


8Sphere logical architecture

ID	Component	Responsibility
CMP-ING	Ingestion and Provenance Gateway	Validates source packages, schemas, classifications, timestamps, and hashes.
CMP-KRN	Mathematical Kernel	Implements canonical base, fiber, radius, differential, projection, spectral, and numerical functions.
CMP-STA	State and Fiber Engine	Constructs bounded five-coordinate states, normalized S3 fibers, trajectories, and quality flags.
CMP-GPH	Coupling Graph Engine	Maintains signed, directed, delayed, and multiplex graphs and their structural measures.
CMP-DYN	Dynamics and Control Engine	Simulates propagation, synchronization, activation, recovery, hysteresis, oscillation, and control.
CMP-LRN	Learning and Calibration Engine	Fits and validates models; manages calibration, uncertainty, shift, and chronological testing.
CMP-RSK	Risk and Resilience Engine	Computes geometric damage, tail risk, attribution, drawdown, liquidity, and robustness.
CMP-SIM	Digital Twin and Scenario Service	Executes isolated, reproducible scenarios without modifying authoritative state.
CMP-DEC	Decision and Intervention Service	Ranks alternatives by benefit, cost, uncertainty, reversibility, and governed limits.
CMP-OBS	8Sphere Observatory	Presents state, networks, risk, model health, alerts, decisions, and evidence.
CMP-EVD	Evidence Ledger	Stores immutable manifests, hashes, artifacts, test results, approvals, and audit lineage.

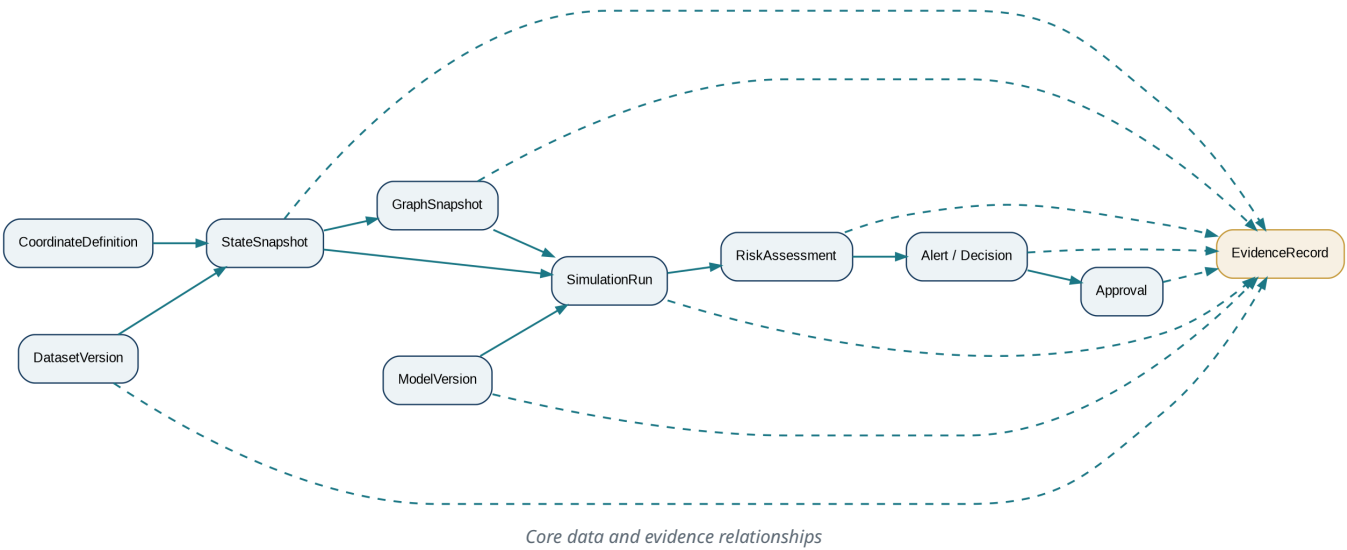
ID	Component	Responsibility
CMP-GOV	Governance Gate	Applies SOPHIA claim limits, CHARLOTTE conformance, LANDON execution evidence, and human authority.
CMP-IAM	Identity and Access Service	Provides authentication, authorization, service identity, and privileged-action control.
CMP-CFG	Configuration and Model Registry	Versions coordinate definitions, models, thresholds, policies, and releases.
CMP-OPS	Deployment and Operations Fabric	Installs, monitors, backs up, restores, updates, rolls back, and recovers the platform.

6. Runtime Processing



- 1. Ingestion assigns provenance and validates the source package.
- 2. State construction applies the approved coordinate and fiber definitions.
- 3. The Mathematical Kernel computes capacity, damage, derivatives, geometry, and diagnostics.
- 4. The Graph Engine updates or analyzes the exact graph snapshot.
- 5. Approved simulation, prediction, or risk workflows execute in controlled workers.
- 6. The Governance Gate checks claim class, validation, known failures, policy, role, and approval.
- 7. The Observatory presents the output and permitted actions.
- 8. The Evidence Ledger commits the complete record.

7. Data Architecture



Authoritative entities include DatasetVersion, CoordinateDefinition, StateSnapshot, GraphSnapshot, ModelVersion, SimulationRun, RiskAssessment, Alert, DecisionRecord, Approval, DeploymentRelease, AuditEvent, and EvidenceRecord. Mutable objects preserve version lineage; EvidenceRecord is append-only.

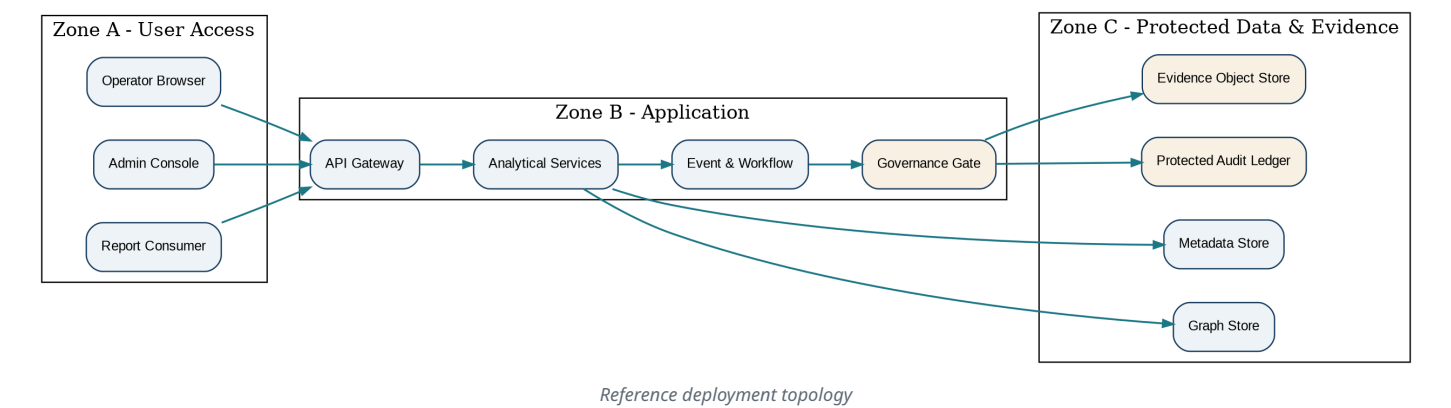
8. Interfaces and Events

Interface	Representative operation	Purpose
API-STATE	POST /v1/states/evaluate	Validate and evaluate an 8Sphere state.
API-GRAPH	POST /v1/graphs/{id}/analyze	Analyze a frozen graph snapshot.
API-SIM	POST /v1/simulations	Run an isolated scenario.
API-RISK	POST /v1/risk/assess	Compute decomposed risk and resilience.
API-DEC	POST /v1/decisions	Create, review, approve, or reject a recommendation.
API-EVD	GET /v1/evidence/{id}	Retrieve immutable evidence.
EVT-STATE	state.created.v1	Publish accepted state.
EVT-ALERT	alert.created.v1 / alert.closed.v1	Publish alert lifecycle.
EVT-GATE	gate.decided.v1	Publish governance outcome.
EVT-RELEASE	release.changed.v1	Publish deployment or rollback status.

9. Security and Trust

The architecture separates untrusted input, controlled processing, and high-integrity evidence/release zones. Every trust transition requires authenticated identity, validation, policy, integrity verification, and audit. Action adapters are disabled by default.

10. Deployment



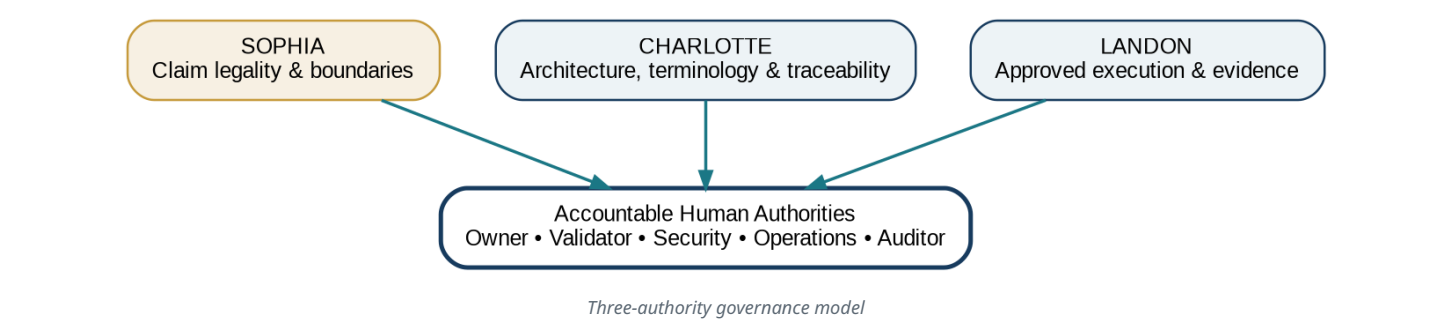
Supported profiles are a single-node development system, an offline laboratory, a private-network operational deployment, and an approved high-availability deployment. The same logical contracts and evidence semantics apply to each profile.

11. Verification and Validation



Labs 1-100 become permanent regressions, but production validation additionally requires frozen domain semantics, real-data quality review, chronological out-of-sample testing, benchmark comparison, realistic cost and latency, security and recovery tests, human-factors validation, shadow operation, and a bounded pilot.

12. Governance



SOPHIA governs claim legality and action classification. CHARLOTTE governs terminology, units, architecture, schemas, and traceability. LANDON performs approved execution and emits reproducible evidence. Accountable humans approve intended use, validation, security, deployment, and material action.

13. Major Risks and Design Responses

Risk	Design response
Unstable coordinate semantics	Version and approve definitions; require transformations for cross-version comparison.
Weakest-link radius may be overinterpreted	Always show contributions, conditioning, alternative softened view, and limitations.
Opaque network scores	Expose paths, communities, bridges, cores, spectral terms, and graph version.
Synthetic results mistaken for empirical evidence	Persistent claim labels and real-data production gate.
Alert overreaction	Cost-based thresholds, hysteresis, human review, rate limits, and kill switch.
Evidence growth	Content-addressed storage, retention classes, legal hold, and compact manifests.
Distributed complexity	Support a modular single-node deployment with identical contracts.

14. Implementation Roadmap

Phase	Scope	Exit
P0 Design baseline	Approve the eleven coordinated design documents.	Critical assumptions, requirements, threats, tests, and gaps are traceable.
P1 Conformance kernel	Kernel, state, schemas, evidence manifest, Labs 1-44.	Deterministic and numerical gates pass.
P2 Twin and network	Graph, dynamics, scenarios, control, Labs 45-60.	Isolation, repeatability, resource, and evidence gates pass.
P3 Learning and risk	Model registry, calibration, uncertainty, risk, Labs 61-83.	Chronological validation and robustness gates pass.
P4 Observatory and governance	Interface, workflows, security, operations, Labs 84-100 controls.	Authorization, audit, rollback, and failure visibility pass.
P5 External pilot	Freeze domain semantics and validate on real data.	Independent validation, shadow mode, pilot, and risk acceptance pass.

15. Consolidated Requirements

ID	Normative requirement
REQ-F-001	Represent every state as five bounded coordinates and one normalized S3 fiber.
REQ-F-002	Compute hard, softened, and weighted capacity radii with versioned parameters.
REQ-F-003	Compute damage contributions, gradients, elasticities, Hessians, curvature, and conditioning.
REQ-F-004	Validate bounds, norm, units, timestamps, missingness, and numerical finiteness before use.
REQ-F-005	Distinguish observed, derived, estimated, simulated, and human-entered values.
REQ-F-006	Compute S3 geodesic, chord, orientation change, and path-dependent transport diagnostics.
REQ-F-007	Represent signed, directed, weighted, delayed, and multiplex relationships.
REQ-F-008	Compute spectral, centrality, influence, community, core, bridge, redundancy, and percolation measures.
REQ-F-009	Simulate propagation, synchronization, activation, recovery, hysteresis, delay, resonance, and feedback.
REQ-F-010	Run isolated targeted and random scenarios with explicit resource and parameter limits.
REQ-F-011	Estimate intervention energy, expected benefit, uncertainty, side effects, and reversibility.
REQ-F-012	Use chronological partitions by default for time-dependent model validation.
REQ-F-013	Measure calibration, conformal coverage, shift, bias-variance, collinearity, sample sufficiency, and leakage.
REQ-F-014	Compare models against frozen benchmarks and versioned thresholds.
REQ-F-015	Compute expected shortfall, tail dependence, diversification, risk budget, drawdown, cost, and liquidity.
REQ-F-016	Quantify sensitivity to missingness, delay, asynchronous data, noise, outliers, heavy tails, adversarial perturbation, and quantization.
REQ-F-017	Decompose predictive uncertainty and preserve human and model contributions in fused decisions.
REQ-F-018	Generate immutable evidence for every material computation, simulation, model, alert, decision, and release.
REQ-F-019	Evidence shall include inputs, hashes, code, configuration, parameters, seed, environment, outputs, tests, and approvals.
REQ-F-020	The Observatory shall expose state, history, claim class, uncertainty, network exposure, model health, alerts, and evidence.
REQ-F-021	Support acknowledgment, investigation, escalation, approval, rejection, dispatch, rollback, and closure workflows.
REQ-F-022	Support single-node, air-gapped, private-network, and high-availability deployment profiles.
REQ-F-023	Provide backup, restore, update, rollback, disaster recovery, and integrity verification.
REQ-F-024	Prevent advisory outputs from becoming autonomous actions without explicit policy and authority.
REQ-Q-001	Deterministic functions shall reproduce byte-stable or tolerance-equivalent outputs from identical signed inputs.
REQ-Q-002	Numerical functions shall meet laboratory tolerances and report conditioning or precision warnings.
REQ-Q-003	Material outputs shall be explainable and traceable to immutable evidence.

ID	Normative requirement
REQ-Q-004	Core operation shall not require a public internet connection.
REQ-Q-005	Graph, simulation, batch, and interactive workloads shall be independently governable and scalable.
REQ-Q-006	The interface and reports shall support keyboard access, meaningful labels, contrast, scalable text, and non-color status cues.
REQ-S-001	Authenticate every user and service before non-public access.
REQ-S-002	Enforce least privilege, separation of duties, and environment-specific authorization.
REQ-S-003	Require recorded approval for privileged changes to models, thresholds, policy, identity, and releases.
REQ-S-004	Protect sensitive data and evidence in transit and at rest.
REQ-S-005	Hash and, where supported, sign releases, evidence, configuration, and offline updates.
REQ-S-006	Sandbox and validate untrusted files, data, models, and removable-media packages.
REQ-S-007	Record protected security and privileged-operation audit events.
REQ-S-008	Support incident containment, credential revocation, evidence preservation, recovery, and review.
REQ-G-001	Assign every output a claim class: mathematical, synthetic, empirical, predictive, advisory, or automated action.
REQ-G-002	SOPHIA shall prevent unsupported promotion of synthetic results to empirical claims.
REQ-G-003	CHARLOTTE shall validate terminology, units, schemas, traceability, and evidence completeness.
REQ-G-004	LANDON shall execute approved workflows and attach reproducible execution evidence.
REQ-G-005	Material releases and actions require independent validation and accountable human approval.
REQ-G-006	Known failures and limitations shall remain visible, including Relationship 91 and Relationship 12 evidence limits.

END OF CONTROLLED DOCUMENT 00

8Sphere System Requirements Specification

DOCUMENT 01

Normative functional, quality, security, governance, interface, data, and operational requirements.

Document ID: 8S-SRS-001
Version: 1.0.0
Status: Engineering design baseline - not production authorization
Source: 8Sphere Relationships 1-100 laboratory evidence and professional expository note

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1. Purpose

This specification states what the 8Sphere system shall do without prescribing a single implementation technology. Requirements are normative unless labeled informative.

2. System Boundary

The system boundary begins at controlled ingestion of data, state, graph, model, configuration, or operator request. It ends at evidence-linked state, analysis, alert, recommendation, decision, report, export, or controlled dispatch. External data providers, enterprise identity, signing infrastructure, and downstream action systems are integrations.

3. Stakeholders and Needs

Stakeholder	Need
Researcher	Reproduce mathematics and extend experiments without contaminating operational evidence.
Domain analyst	Define semantics, inspect contributions, run scenarios, and compare alternatives.

Stakeholder	Need
Operator	Monitor state and health, investigate alerts, and follow controlled workflows.
Decision authority	Receive explainable alternatives, uncertainty, evidence, and rollback conditions.
Independent validator	Re-run tests, challenge assumptions, and record approval or defects.
Security and operations	Deploy, monitor, protect, recover, update, and contain the platform.
Auditor	Trace every material claim and action to evidence, requirements, and approvals.

4. Operational Use Cases

ID	Use case	Required outcome
UC-001	Evaluate state	Validate source and definitions; compute state, capacity, diagnostics, claim class, and evidence.
UC-002	Analyze graph	Compute approved structural, influence, propagation, and resilience measures on a frozen graph.
UC-003	Run scenario	Create an isolated branch from frozen versions; execute, compare, and commit evidence.
UC-004	Train and validate	Use frozen data partitions, benchmark, costs, metrics, and acceptance before execution.
UC-005	Investigate alert	Review cause, contributors, uncertainty, model/data health, evidence, and related incidents.
UC-006	Approve intervention	Review alternatives, cost, uncertainty, authority, reversibility, and rollback.
UC-007	Release system	Verify signed package, compatibility, regressions, security, staged deployment, and rollback.
UC-008	Audit claim	Follow a claim through data, code, model, configuration, tests, approvals, and exports.

5. Normative Requirements

ID	Normative requirement
REQ-F-001	Represent every state as five bounded coordinates and one normalized S3 fiber.
REQ-F-002	Compute hard, softened, and weighted capacity radii with versioned parameters.
REQ-F-003	Compute damage contributions, gradients, elasticities, Hessians, curvature, and conditioning.
REQ-F-004	Validate bounds, norm, units, timestamps, missingness, and numerical finiteness before use.
REQ-F-005	Distinguish observed, derived, estimated, simulated, and human-entered values.
REQ-F-006	Compute S3 geodesic, chord, orientation change, and path-dependent transport diagnostics.
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REQ-F-010	Run isolated targeted and random scenarios with explicit resource and parameter limits.
REQ-F-011	Estimate intervention energy, expected benefit, uncertainty, side effects, and reversibility.
REQ-F-012	Use chronological partitions by default for time-dependent model validation.
REQ-F-013	Measure calibration, conformal coverage, shift, bias-variance, collinearity, sample sufficiency, and leakage.
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REQ-F-015	Compute expected shortfall, tail dependence, diversification, risk budget, drawdown, cost, and liquidity.
REQ-F-016	Quantify sensitivity to missingness, delay, asynchronous data, noise, outliers, heavy tails, adversarial perturbation, and quantization.
REQ-F-017	Decompose predictive uncertainty and preserve human and model contributions in fused decisions.
REQ-F-018	Generate immutable evidence for every material computation, simulation, model, alert, decision, and release.
REQ-F-019	Evidence shall include inputs, hashes, code, configuration, parameters, seed, environment, outputs, tests, and approvals.
REQ-F-020	The Observatory shall expose state, history, claim class, uncertainty, network exposure, model health, alerts, and evidence.

ID	Normative requirement
REQ-F-021	Support acknowledgment, investigation, escalation, approval, rejection, dispatch, rollback, and closure workflows.
REQ-F-022	Support single-node, air-gapped, private-network, and high-availability deployment profiles.
REQ-F-023	Provide backup, restore, update, rollback, disaster recovery, and integrity verification.
REQ-F-024	Prevent advisory outputs from becoming autonomous actions without explicit policy and authority.
REQ-Q-001	Deterministic functions shall reproduce byte-stable or tolerance-equivalent outputs from identical signed inputs.
REQ-Q-002	Numerical functions shall meet laboratory tolerances and report conditioning or precision warnings.
REQ-Q-003	Material outputs shall be explainable and traceable to immutable evidence.
REQ-Q-004	Core operation shall not require a public internet connection.
REQ-Q-005	Graph, simulation, batch, and interactive workloads shall be independently governable and scalable.
REQ-Q-006	The interface and reports shall support keyboard access, meaningful labels, contrast, scalable text, and non-color status cues.
REQ-S-001	Authenticate every user and service before non-public access.
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REQ-S-003	Require recorded approval for privileged changes to models, thresholds, policy, identity, and releases.
REQ-S-004	Protect sensitive data and evidence in transit and at rest.
REQ-S-005	Hash and, where supported, sign releases, evidence, configuration, and offline updates.
REQ-S-006	Sandbox and validate untrusted files, data, models, and removable-media packages.
REQ-S-007	Record protected security and privileged-operation audit events.
REQ-S-008	Support incident containment, credential revocation, evidence preservation, recovery, and review.
REQ-G-001	Assign every output a claim class: mathematical, synthetic, empirical, predictive, advisory, or automated action.
REQ-G-002	SOPHIA shall prevent unsupported promotion of synthetic results to empirical claims.
REQ-G-003	CHARLOTTE shall validate terminology, units, schemas, traceability, and evidence completeness.
REQ-G-004	LANDON shall execute approved workflows and attach reproducible execution evidence.
REQ-G-005	Material releases and actions require independent validation and accountable human approval.
REQ-G-006	Known failures and limitations shall remain visible, including Relationship 91 and Relationship 12 evidence limits.

6. External Interface Requirements

ID	Requirement
REQ-I-001	Machine interfaces shall use versioned schemas and idempotency identifiers for material writes.
REQ-I-002	Timestamps shall include timezone or normalize to UTC while preserving the source value.
REQ-I-003	Bulk ingestion shall validate a manifest and permit partial rejection without silent acceptance.
REQ-I-004	Exports shall contain human-readable content and a machine-readable hash/evidence manifest.
REQ-I-005	The platform shall support API, event, file-package, and offline removable-media integration.
REQ-I-006	Downstream action interfaces shall be disabled by default.
REQ-I-007	Errors shall include stable code, explanation, correlation identifier, and evidence or audit reference.
REQ-I-008	Interfaces and exports shall not expose secrets or protected internal traces.

7. Acceptance Criteria

1. Every requirement has an owner, implementation reference, verification method, and evidence artifact.

2. Labs 1-100 execute from the approved release and reproduce their expected verdicts, including Relationship 91 as FAIL until superseded by an approved new protocol.
3. No unresolved critical integrity, authorization, security, backup, or rollback defect remains.
4. A target-profile installation, backup, restore, update, and rollback rehearsal succeeds.
5. Domain semantics and external validation are approved before predictive or performance claims.

Preserved limitations. Relationship 91 remains a failed baseline gate because its false-alarm rate exceeded the frozen ceiling. Relationship 12 retains a run-level evidence-availability limitation. Neither condition may be hidden by the aggregate pass count.

END OF CONTROLLED DOCUMENT 01

8Sphere Software Architecture Document

DOCUMENT 02

Component boundaries, services, events, runtime flows, deployment topology, and technology constraints.

Document ID: 8S-SAD-001

Version: 1.0.0

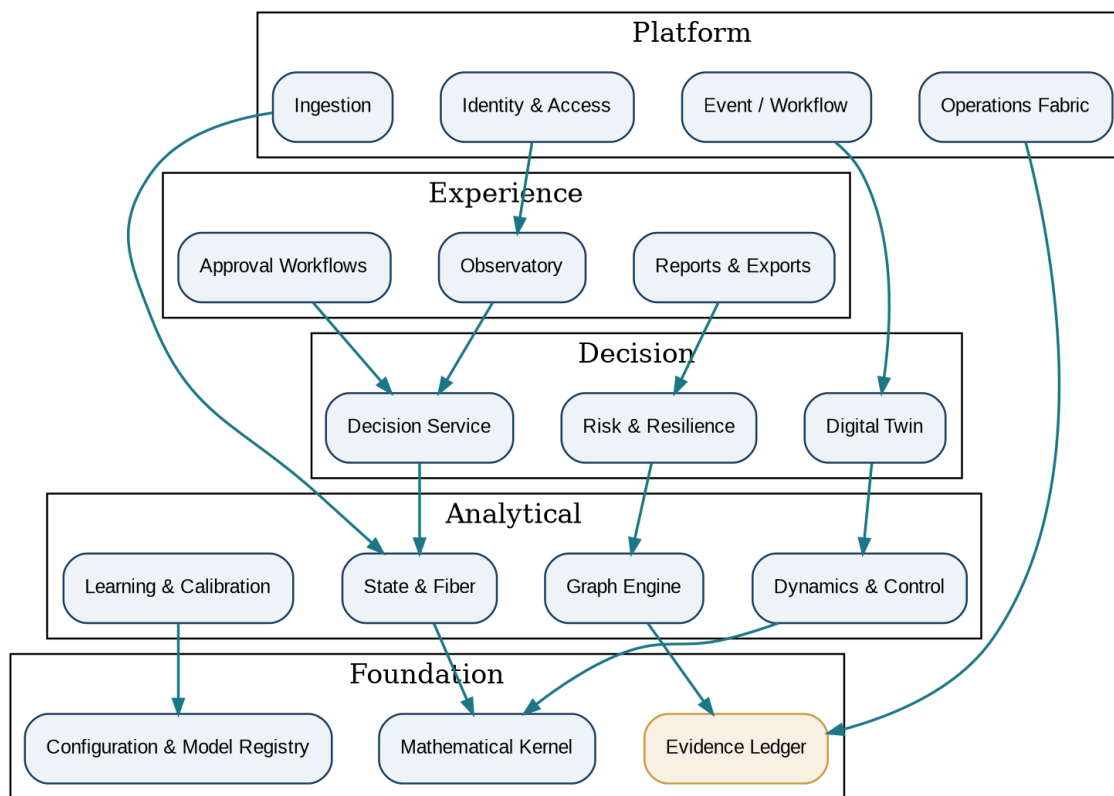
Status: Engineering design baseline - not production authorization

Source: 8Sphere Relationships 1-100 laboratory evidence and professional expository note

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1. Architecture Overview

The design uses logical services with stable contracts. The same architecture may run in one process or across independently scaled services. Analytical meaning is defined by schemas, versions, conformance tests, and evidence rather than by a particular vendor or framework.



Logical architecture

2. Architecture Drivers

- Reproducible mathematics and simulations.
- Separation of observed, derived, synthetic, predictive, advisory, and action states.
- Air-gapped and private deployment.

- Independent workload scaling and isolation.
- Append-only evidence and auditable approvals.
- Framework-neutral portability.

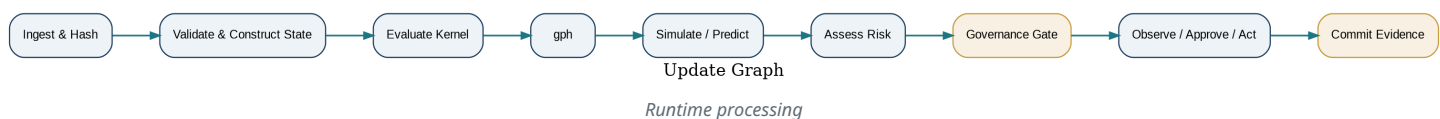
3. Components

ID	Component	Responsibility
CMP-ING	Ingestion and Provenance Gateway	Validates source packages, schemas, classifications, timestamps, and hashes.
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CMP-IAM	Identity and Access Service	Provides authentication, authorization, service identity, and privileged-action control.
CMP-CFG	Configuration and Model Registry	Versions coordinate definitions, models, thresholds, policies, and releases.
CMP-OPS	Deployment and Operations Fabric	Installs, monitors, backs up, restores, updates, rolls back, and recovers the platform.

4. Component Contracts

Component	Input → Output	Contract
CMP-ING	DatasetPackage → IngestionResult	Validate manifest, hashes, schema, classification, and provenance; accept or quarantine.
CMP-KRN	StateVector + KernelConfig → KernelEvaluation	Pure deterministic calculation with function version and numerical diagnostics.
CMP-STA	ValidatedObservation + CoordinateDefinition → StateSnapshot	Apply transforms, normalize fiber, record missingness, quality, and source evidence.
CMP-GPH	GraphSnapshot + AnalysisRequest → GraphAnalysis	Analyze an exact immutable graph version.
CMP-DYN	InitialState + DynamicLaw + Scenario → Trajectory	Execute in isolated worker with resource limits and checkpoints.
CMP-LRN	DatasetVersion + ModelSpec + ValidationPlan → ModelEvaluation	Use frozen partitions, benchmarks, metrics, and seed policy.
CMP-RSK	State/Trajectory + RiskPolicy → RiskAssessment	Return decomposed risk, contributors, thresholds, uncertainty, and limitations.
CMP-DEC	Risk + Alternatives + AuthorityPolicy → DecisionPacket	Rank alternatives; dispatch only after governance and authority.
CMP-EVD	EvidenceEnvelope → EvidenceRecord	Verify required fields and hashes; append immutable record.
CMP-GOV	Claim + Evidence + Actor → GateDecision	Check claim class, validation, known failures, policy, role, and approvals.

5. Runtime Views



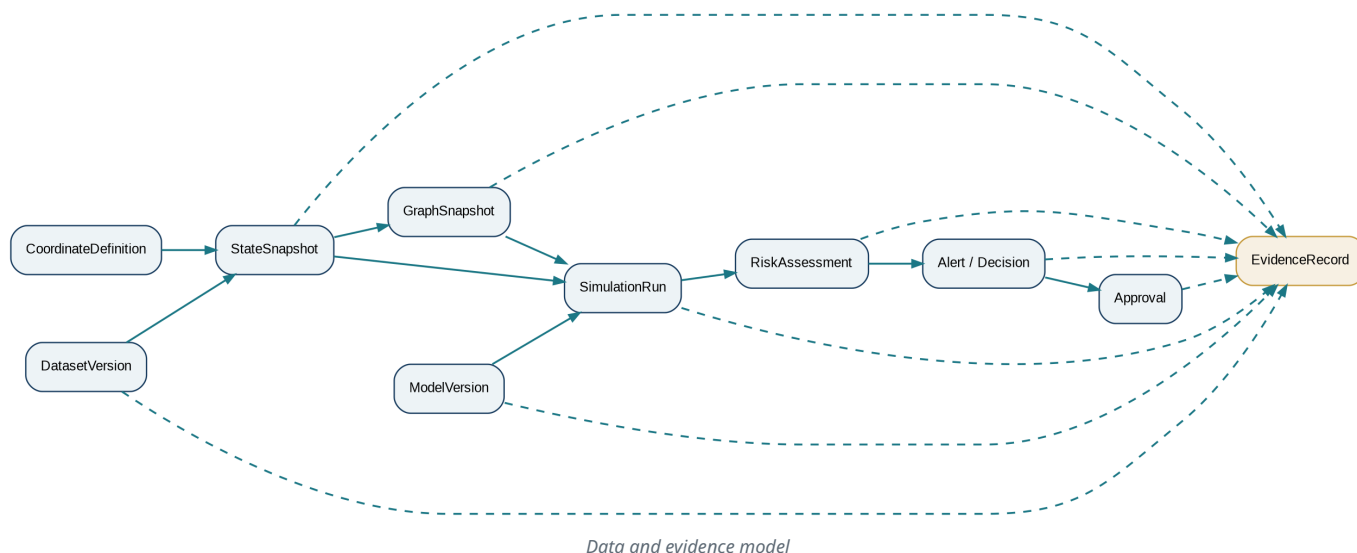
5.1 State evaluation sequence

1. Client obtains coordinate and schema versions.
2. Ingestion validates and commits source provenance.
3. State Engine applies transformations and invokes the Mathematical Kernel.
4. Evidence Ledger commits the result bundle.
5. Governance Gate assigns claim class and restrictions.
6. API returns state, quality, diagnostics, and evidence identifier.

5.2 Scenario and decision sequence

1. Freeze baseline state, graph, models, policies, and parameters.
2. Create an isolated Digital Twin branch.
3. Execute dynamics, graph, learning, and risk analyses.
4. Compare alternatives and reversibility.
5. Apply governance and human approval.
6. Dispatch only through a separately controlled adapter.
7. Commit inputs, outputs, approvals, and receipts.

6. Data and Storage



Data and evidence model

Store	Authoritative content	Required property
Metadata store	definitions, versions, workflow, approvals, pointers	transactional lineage and consistency
Graph store	nodes, edges, layers, validity intervals, graph indexes	snapshot isolation and deterministic export
Evidence object store	inputs, outputs, reports, figures, code, manifests	content-addressed immutability
Protected audit ledger	identity, changes, approvals, exports, releases	append-only restricted write
Working store	cache and checkpoints	non-authoritative and rebuildable

7. Events

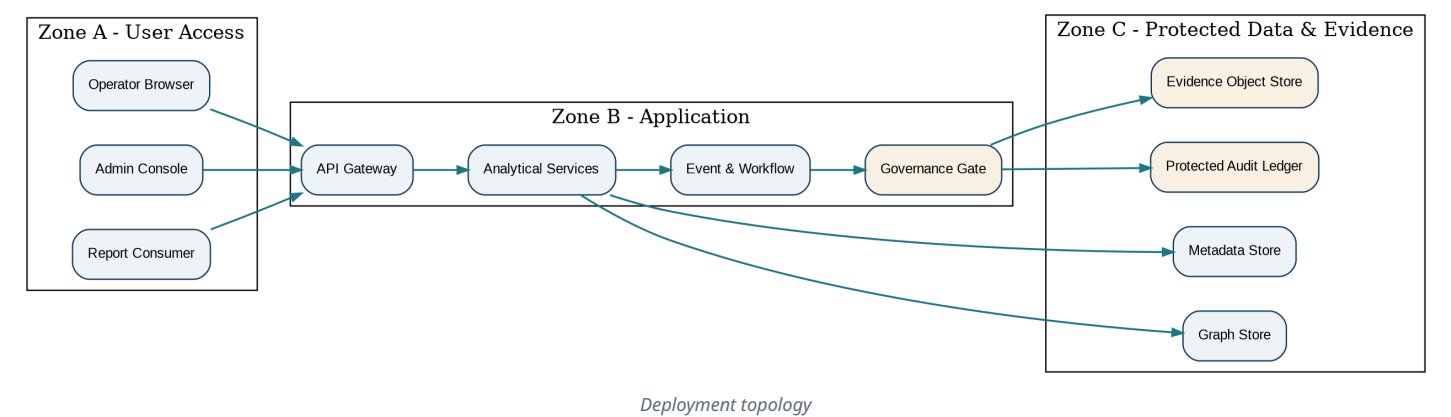
Event	Producer	Minimum content
dataset.accepted.v1	CMP-ING	dataset ID, hash, classification, schema, provenance
state.created.v1	CMP-STA	state ID, definition version, quality, evidence ID
simulation.completed.v1	CMP-SIM	run ID, baseline versions, status, evidence ID
model.evaluated.v1	CMP-LRN	model version, metrics, validation plan, evidence ID
alert.created.v1	CMP-RSK / CMP-OBS	severity, reason, contributors, evidence ID
gate.decided.v1	CMP-GOV	claim class, decision, conditions, approvals
release.changed.v1	CMP-OPS	release, environment, rollback target, evidence ID

8. Failure and Degraded Modes

Failure	Required behavior
Evidence unavailable	Stop material completion or hold a protected pending transaction; do not claim commitment.
Worker failure	Fail or resume from evidence-linked checkpoint; do not promote partial output.

Failure	Required behavior
Predictive service unavailable	Permit deterministic functions only when policy allows; label predictive status unavailable.
Poor data quality	Reject or mark degraded; block actions according to policy.
Ordering or clock anomaly	Quarantine until source time and sequence are resolved.
Authorization failure	Fail closed for privileged action.

9. Deployment View



10. Architecture Decisions

Decision	Rationale	Tradeoff
Logical services with single-node option	Clear boundaries without mandatory distributed complexity.	Distributed scale adds administration.
Append-only evidence	Protects history and correction lineage.	Storage growth.
Event-driven workflows	Supports replay, audit, and long-running jobs.	Requires ordering and idempotency discipline.
Separate Digital Twin	Prevents experiments from changing authoritative state.	Requires version synchronization.
Explicit Governance Gate	Makes claim and action authority inspectable.	Adds policy maintenance and latency.
Framework-neutral contracts	Portability and long-term reproducibility.	Requires adapters and canonical exports.

END OF CONTROLLED DOCUMENT 02

8Sphere Mathematical and Algorithmic Specification

DOCUMENT 03 Authoritative formulas, assumptions, tolerances, numerical methods, and executable pseudocode.

Document ID: 8S-MAS-001
Version: 1.0.0
Status: Engineering design baseline - not production authorization
Source: 8Sphere Relationships 1-100 laboratory evidence and professional expository note

Controlled-use notice. This document is an engineering design artifact. The laboratory program establishes internal mathematical and synthetic consistency under documented conditions. It does not independently establish real-world predictive performance or authorize automated financial or operational action.

1. Authority and Scope

This document defines the canonical mathematics, assumptions, numerical safeguards, and reference algorithms. Domain meanings are versioned configuration and may not silently alter the core formulas.

2. State and Capacity

The serialized local state is $X=(b_1,...,b_5,q_0,q_1,q_2,q_3)X=(b_1,\ldots,b_5,q_0,q_1,q_2,q_3)$ with $b_i\in[-1,1]b_i\in[-1,1]$ and $\|q\|_2=1\|q\|_2=1$. The four-component fiber has three intrinsic degrees of freedom.

$$r(b)=\prod_i\max(0,1-b_i^2)r(b)=\prod_i\sqrt{\max(0,1-b_i^2)}$$
$$r\epsilon,\nu(b)=\prod_i(\epsilon+1-b_i^2)^{\nu_i/2r_{\{\epsilon,\nu\}}(b)=\prod_i(\epsilon+1-b_i^2)^{\nu_i/2}}$$
$$D(b)=-\log r(b)=-12\sum_i\log(1-b_i^2)D(b)=-\log r(b)=-\frac{12}{2}\sum_i\log(1-b_i^2)$$

Coordinate damage is $d_i = -12 \log(1 - b_i^2) d_i = -\frac{12 \log(1 - b_i^2)}{2}$ and, when total damage is positive, contribution share is $p_i = d_i / \sum_j d_j$.

3. Differential Structure

Quantity	Expression
Gradient	$\partial r / \partial b_i = -r b_i / (1 - b_i^2) \partial r / \partial b_i = -r b_i / (1 - b_i^2)$
Elasticity	$\partial \log r / \partial \log \ b\ = -b_i^2 / (1 - b_i^2) \partial \log r / \partial \log \ b\ = -b_i^2 / (1 - b_i^2)$
Mixed derivative	$\partial^2 r / (\partial b_i \partial b_j) = r b_i b_j / [(1 - b_i^2)(1 - b_j^2)] \partial^2 r / (\partial b_i \partial b_j) = r b_i b_j / [(1 - b_i^2)(1 - b_j^2)]$
Coordinate curvature	$\partial^2 r / \partial b_i^2 = -r / (1 - b_i^2)^2 \partial^2 r / \partial b_i^2 = -r / (1 - b_i^2)^2$
Effective dimension	$D_{\text{eff}} = (\sum_i \lambda_i) / 2 \sum_i \lambda_i^2 D_{\text{eff}} = (\sum_i \lambda_i) / 2 \sum_i \lambda_i^2$
Contribution entropy	$H = -\sum_i p_i \log p_i / \log 5 H = -\sum_i p_i \log p_i / \log 5$

Near $|b_i| = 1$ $|b_i| = 1$, the hard radius reaches zero and derivatives become ill-conditioned. Implementations shall use log-domain products, emit boundary/conditioning flags, and label any softened radius separately.

4. S3 Geometry and Transport

$dS_3(q_a, q_b) = \arccos(\text{clip}(q_a \cdot q_b, -1, 1)) d_{\{S^3\}}(q_a, q_b) = \arccos(\text{clip}(q_a \cdot q_b, -1, 1))$
 $\|q_a - q_b\|_2 = 2 \sin(dS_3/2) \|q_a - q_b\|_2 = 2 \sin(d_{\{S^3\}}/2)$
Prototype transport uses $q_{\text{next}} = \exp(A(\Delta b)) q q_{\text{next}} = \exp(A(\Delta b)) q$ with versioned skew-symmetric generators. Closed noncommuting loops may retain a residual orientation; path and generator version are evidence.

5. Projection and Information

- A projection $y = P_k x y = P_k x$ always records $P_k P_k$, source dimension, target dimension, and reconstruction policy.
- PCA reconstruction residual equals the omitted eigenvalue mass under the documented normalization.
- Capacity level-set volume is $V(c) = P[r(b) \geq c] V(c) = P[r(b) \geq c]$ under a named sampling distribution.
- Mutual-information estimators record distributional assumptions, estimator, binning or kernel parameters, and uncertainty.

6. Graph and Cascade Mathematics

Family	Contract
Signed directed graph	Each edge records source, target, sign, weight, delay, layer, confidence, and validity.
Systemic influence	Propagation operator identifies normalization, convergence range, and exact graph snapshot.
Spectral threshold	α_c is analyzed relative to $1/p(W)1/\rho(W)$ with topology residuals preserved.
Synchronization	$R = \ N - 1 \sum_j e^{i\theta_j}\ R = \ N - 1 \sum_j e^{i\theta_j}\ $.
Activation	$a_{t+1} = \sigma(\alpha W a_t + b) a_{t+1} = \sigma(\alpha W a_t + b)$ with update order and convergence rule.
k-core and community	Projection rules for direction, weight, and multiplex layers are explicit.
Propagation time	Unit-delay arrival equals graph distance; weighted/delayed cases use shortest travel time.

7. Dynamics and Control

Family	Reference relation
Linear recovery	$x_{t+1} = a x_t x_{t+1} = a x_t$ and $T = \lceil \log(\text{target} / \ x_0\) / \log \ a\ \rceil T = \lceil \log(\text{target} / \ x_0\) / \log \ a\ \rceil$.
Lyapunov	λ is estimated from the slope of $\log \ \delta x_t\ \log \ \delta x_t\ $.
Hysteresis	$H = \int \ A_{\text{up}}(\alpha) - A_{\text{down}}(\alpha)\ d\alpha H = \int \ A_{\text{up}}(\alpha) - A_{\text{down}}(\alpha)\ d\alpha$.
Damping overshoot	$M_p = \exp[-\zeta \pi / (1 - \zeta^2)] M_p = \exp[-\zeta \pi / \sqrt{1 - \zeta^2}]$.
Control energy	Minimum-energy control uses the finite-horizon controllability Gramian.
Resonance	Frequency response records natural frequency, damping, forcing, and sampling.
Adaptive feedback	Estimator, control law, saturation, stability range, and version are explicit.

8. Learning, Validation, Risk, and Robustness

- Chronological partitioning is the default for time-dependent claims.
- Calibration, discrimination, decision cost, uncertainty, and threshold stability are reported separately.
- Identifiability requires sufficient excitation; low fit error alone is insufficient.
- Expected shortfall, tail dependence, risk attribution, transaction cost, and liquidity assumptions are versioned.

- Missingness, delay, asynchronous sampling, label noise, outliers, heavy tails, adversarial perturbation, and quantization are separate stress families.

9. Numerical Safeguards

ID	Default intent
NUM-001	Use 1e-12 for exact double-precision identities unless a laboratory defines another tolerance.
NUM-002	Use 1e-10 for normal fiber and reversibility checks.
NUM-003	Adapt finite-difference steps to scale and conditioning.
NUM-004	Warn initially at $\ b_i\ \geq 0.95 \vee \ b_{i'}\ \geq 0.95$; deployment may approve another threshold.
NUM-005	Reject out-of-bound coordinates beyond configured input tolerance.
NUM-006	Use stable log-domain evaluation near underflow.
NUM-007	Record seed hierarchy, generator, runtime, and dependency versions.
NUM-008	NaN, infinity, singularity, nonconvergence, or tolerance failure produces explicit status.

10. Reference Pseudocode

```
function evaluate_state(observation, coordinate_definition, config):
  validate_schema_units_bounds(observation, coordinate_definition)
  b <- transform_to_bounded_coordinates(observation)
  q <- observe_or_estimate_fiber(observation)
  require abs(norm(q)-1) <= fiber_tolerance
  r, log_r <- stable_capacity(b, config)
  contributions <- coordinate_damage(b)
  gradient, hessian, conditioning <- differential_diagnostics(b)
  flags <- quality_and_boundary_flags(b, conditioning)
  return StateEvaluation(b,q,r,-log_r,contributions,gradient,hessian,flags)

function commit_evidence(run):
  envelope <- canonicalize(inputs, versions, config, seed, environment, outputs, tests, approvals)
  object_hashes <- store_content_addressed_artifacts(envelope.artifacts)
  manifest_hash <- hash(canonical_manifest(envelope, object_hashes))
  append EvidenceRecord(manifest_hash, object_hashes, lineage, status)
  return immutable_evidence_id

function governance_gate(claim, evidence, actor, policy):
  require evidence.complete and evidence.integrity_valid
  claim_class <- SOPHIA.classify(claim, evidence)
  CHARLOTTE.validate_terms_units_traceability(claim, evidence)
  LANDON.verify_execution_attestation(evidence)
  return policy.decision(claim_class, actor, risk, approvals, known_failures)
```

Preserved limitations. Relationship 91 remains a failed baseline gate because its false-alarm rate exceeded the frozen ceiling. Relationship 12 retains a run-level evidence-availability limitation. Neither condition may be hidden by the aggregate pass count.

END OF CONTROLLED DOCUMENT 03

8Sphere Data and Evidence Specification

DOCUMENT 04

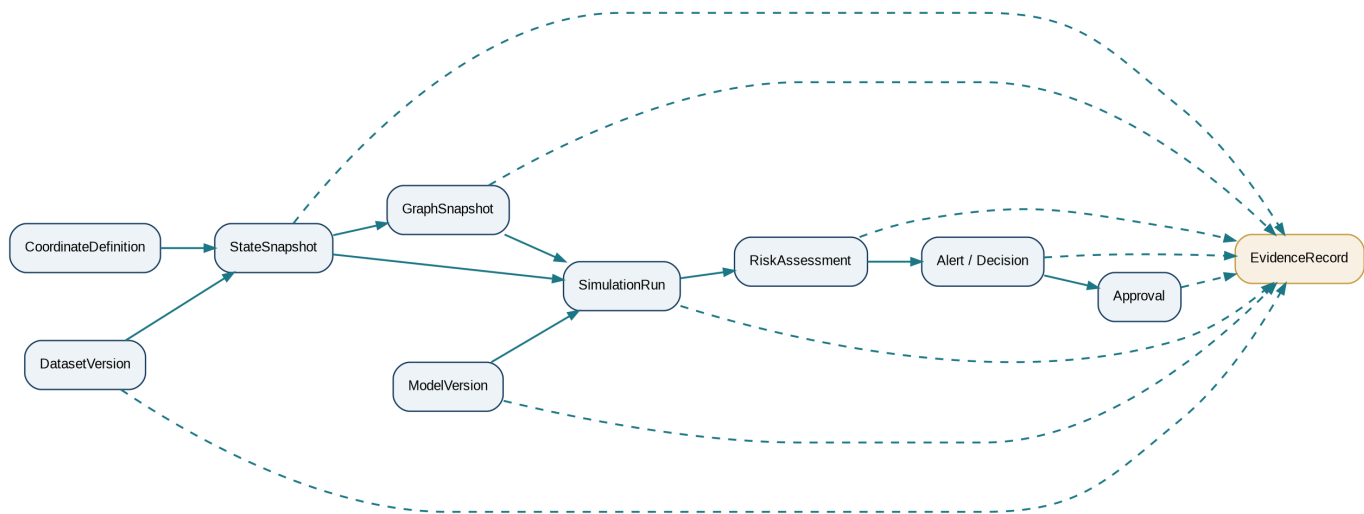
Data schemas, evidence lineage, provenance, versioning, retention, reproducibility, and audit controls.

Document ID: 8S-DES-001
Version: 1.0.0
Status: Engineering design baseline - not production authorization
Source: 8Sphere Relationships 1-100 laboratory evidence and professional expository note

Controlled-use notice. This document is an engineering design artifact. The laboratory program establishes internal mathematical and synthetic consistency under documented conditions. It does not independently establish real-world predictive performance or authorize automated financial or operational action.

1. Purpose

This specification defines authoritative entities, provenance, versioning, retention, reproducibility, audit, and evidence integrity.



Data and evidence relationships

2. Classification

Class	Examples	Minimum controls
Public	approved public specifications and reports	integrity and version control
Internal	ordinary configuration and model metrics	authenticated access and audit
Sensitive	licensed data, business state, proprietary models	encryption, least privilege, export control
Restricted	credentials, signing keys, regulated data	segregated storage, dual control, enhanced monitoring
Evidence-critical	manifests, approvals, releases, authoritative output	append-only integrity and retention hold

3. Authoritative Entities

Entity	Minimum fields
CoordinateDefinition	ID, version, name, unit, source, transform, range, direction, missingness, owner, approval, supersedes
StateSnapshot	ID, time, definitions, source and bounded values, fiber, capacity, damage, contributions, quality, provenance, kernel, evidence
GraphSnapshot	ID, version, valid time, node/edge hashes, sign/direction/layer/delay rules, source, evidence
ModelVersion	ID, version, purpose, claim class, features, training data, code, parameters, validation, metrics, limitations, approval, evidence
SimulationRun	ID, baseline versions, scenario, seed, environment, checkpoints, outputs, status, evidence
RiskAssessment	ID, source state/run, policy, measures, contributors, thresholds, uncertainty, limitations, evidence
Alert	ID, type, severity, status, reason, contributors, threshold, owner, workflow, evidence
DecisionRecord	ID, alternatives, recommendation, human decision, rationale, authority, conditions, receipt, rollback, evidence
EvidenceRecord	ID, manifest hash, object hashes, lineage, code, configuration, seed, environment, tests, approvals, status, supersedes

4. Evidence Envelope

Section	Required content
Identity	evidence ID, run ID, operation, time, environment, actor/service identity
Inputs	data, state, graph, model, policy, and configuration versions plus hashes
Execution	code release, dependency lock, runtime package, hardware when material, seed and generator
Method	algorithm, parameters, tolerances, validation plan, benchmark, cost assumptions
Outputs	canonical results, reports, figures, and logs required for interpretation
Verification	unit, regression, integration, quality, security, and acceptance outcomes
Governance	claim class, limitations, known failures, approvals, exceptions, review date
Integrity	manifest and object hashes, signature or attestation, locations, supersession

5. Provenance Rules

1. Every transformation creates a new versioned object; source objects are not overwritten.
2. State traces to source observations and coordinate definitions.
3. Prediction traces to model, features, data, code, and exact state.
4. Recommendation traces to predictions, risk, alternatives, costs, policy, and approvals.
5. Correction creates a superseding record and preserves the original.
6. Exports retain evidence identifiers and an independently verifiable manifest.

6. Versioning

Object	Rule	Compatibility
Schema	major.minor.patch	major change requires migration or adapter
Coordinate definition	immutable semantic version	cross-version comparison requires approved transformation
Kernel	release plus function version	result records function and tolerance profile
Graph	immutable snapshot	analysis references node/edge hashes
Model	immutable model version	retraining creates a new version
Policy/threshold	immutable approved version	retain effective and expiration dates
Evidence	content-addressed ID	never modified; supersession only
Release	signed release ID	requires rollback and migration plan

7. Retention Classes

Class	Intent	Disposition
R0 Working	cache, scratch, checkpoints	remove after evidence commit or timeout
R1 Operational	ordinary state and alert history	retain for operational review horizon
R2 Validation	training, testing, benchmarks, laboratories	retain through model lifecycle and audit
R3 Decision	material recommendations, approvals, actions, outcomes	long-term domain-policy retention
R4 Security	incidents, access, privileged change	restricted retention and legal hold
R5 Foundational	specifications, releases, signatures, evidence manifests	archival or permanent

8. Reproducibility Package

A complete package contains input manifests and hashes, code and dependency lock, configuration and definitions, model and policy versions, seed hierarchy, runtime details, raw and summarized results, figures, logs required to understand failures, acceptance verdict, and independent rerun comparison when required.

9. Audit Events

Identity, ingestion, classification, export, model registration, validation, threshold change, evidence commit, approval, decision, dispatch, rollback, install, update, backup, restore, failover, and incident actions are protected audit events.

Preserved limitations. Relationship 91 remains a failed baseline gate because its false-alarm rate exceeded the frozen ceiling. Relationship 12 retains a run-level evidence-availability limitation. Neither condition may be hidden by the aggregate pass count.

END OF CONTROLLED DOCUMENT 04

8Sphere Interface and Observatory Design Specification

DOCUMENT 05 Observatory dashboards, workflows, alerts, controls, accessibility, and human-review patterns.

Document ID: 8S-IOD-001
Version: 1.0.0
Status: Engineering design baseline - not production authorization
Source: 8Sphere Relationships 1-100 laboratory evidence and professional expository note

Controlled-use notice. This document is an engineering design artifact. The laboratory program establishes internal mathematical and synthetic consistency under documented conditions. It does not independently establish real-world predictive performance or authorize automated financial or operational action.

1. Design Intent

The Observatory must show what is known, how it was produced, how uncertain it is, what failed, and what actions are permitted. It renders authoritative service results and does not reproduce critical mathematics in the browser.

2. Roles

Role	Primary access	Prohibited or restricted
Viewer	approved dashboards and reports	no changes
Analyst	state, network, scenario, model, and risk workspaces	no release or production-action approval
Operator	alerts, evidence, health, run controls	no semantic redefinition
Decision authority	alternatives, recommendations, approval and dispatch status	only within delegated authority
Validator	plans, evidence, defects, comparison, sign-off	no self-approval of own implementation
Administrator	identity, configuration, deployment, backup	no claim override
Auditor	read-only evidence and audit	no operational change

3. Information Architecture

Global navigation: Overview, States, Networks, Scenarios, Models, Risk, Alerts, Decisions, Evidence, System Health, Administration.

Panel	Required content	Primary interaction
State and capacity	five coordinates, fiber, radius, damage, contributions, boundary distance, quality	time and version comparison; source inspection
Network exposure	graph, communities, bridges, cores, influence, propagation, confidence	layer filter, node/edge details, scenario launch
Dynamics	trajectory, synchronization, activation, hysteresis, recovery, control	baseline/scenario comparison
Risk	tail risk, drawdown, liquidity, risk budget, scenario composition	contributor and threshold drilldown
Model health	version, benchmark, discrimination, calibration, coverage, shift, leakage, reproducibility	open validation and limitations
Alerts	severity, cause, contributors, confidence, owner, age, state	acknowledge, investigate, escalate, close
Evidence drawer	inputs, code, parameters, seed, tests, approvals, hashes, exports	verify and follow lineage

4. Visual Semantics

Element	Rule
Status	Use text and icon in addition to color: PASS, FAIL, DEGRADED, UNKNOWN, PENDING, BLOCKED.
Claim class	Persistent label on every material result.
Uncertainty	Show interval or band, definition, source, and coverage or confidence.
Threshold	Show version, direction, owner, and effective date.
Comparison	Use common scale and label baseline, scenario, model, and period.
Missing data	Separate observed, missing, and imputed values.
Evidence	Every material card links to evidence and result version.

5. Workflows

5.1 Investigate an alert

1. Confirm environment, severity, state, and age.
2. Review contributors, uncertainty, threshold, and data quality.
3. Inspect network and trajectory context.
4. Open evidence and model-health records.
5. Acknowledge, assign, escalate, suppress with approved reason, or close.

5.2 Run a scenario

1. Select immutable baseline versions.
2. Define bounded perturbation or intervention.
3. Review resource estimate and claim class.
4. Execute in the Digital Twin.
5. Compare outcomes and limitations.
6. Commit interpretation and evidence.

5.3 Approve a recommendation

- 1. Confirm authority and intended use.
- 2. Review alternatives, benefit, cost, uncertainty, reversibility, and rollback.
- 3. Check validation, failures, and exceptions.
- 4. Approve, reject, revise, or defer with rationale.
- 5. Dispatch only through an authorized adapter.

6. Alerts

Severity	Meaning	Response
Informational	observation with no immediate action	record and normal review
Low	minor issue	assign and monitor
Moderate	credible degradation or exposure	timely investigation
High	material risk, integrity, security, or service failure	immediate escalation
Critical	ongoing or imminent unacceptable impact or unauthorized action	containment and incident command

Alert policies define deduplication, correlation, hysteresis, suppression authority, escalation, age, and false-alarm review. Relationship 91 requires a visible caution on change-point alerts.

7. Accessibility

The interface supports complete keyboard operation, visible focus, programmatic labels, text alternatives and tables for charts, non-color status cues, contrast, scalable typography, reduced motion, plain-language summaries, and locale-aware display while preserving canonical values.

8. Overrides

Overrides record authority, reason, duration, scope, consequence, compensating control, rollback, and evidence. High-risk overrides require dual approval.

9. Error States

No-data, degraded-data, computation-failed, evidence-unavailable, permission-denied, and known-validation-failure states explain cause, consequence, evidence, and permitted next action.

Preserved limitations. Relationship 91 remains a failed baseline gate because its false-alarm rate exceeded the frozen ceiling. Relationship 12 retains a run-level evidence-availability limitation. Neither condition may be hidden by the aggregate pass count.

END OF CONTROLLED DOCUMENT 05

8Sphere Security and Threat Model

DOCUMENT 06

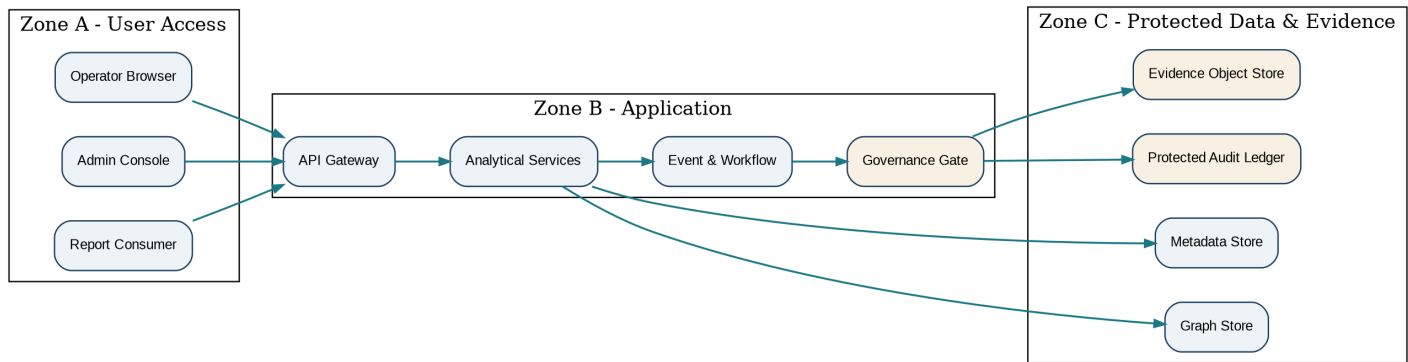
Assets, adversaries, attack surfaces, trust zones, mitigations, detection, and incident response.

Document ID: 8S-STM-001
Version: 1.0.0
Status: Engineering design baseline - not production authorization
Source: 8Sphere Relationships 1-100 laboratory evidence and professional expository note

Controlled-use notice. This document is an engineering design artifact. The laboratory program establishes internal mathematical and synthetic consistency under documented conditions. It does not independently establish real-world predictive performance or authorize automated financial or operational action.

1. Security Objective

Protect analytical integrity, sensitive data, model/configuration authority, evidence provenance, service availability, and the boundary between advisory computation and real-world action.



Deployment trust boundaries

2. Assets and Adversaries

Assets include source and derived data, definitions, graphs, models, thresholds, code, releases, evidence, credentials, signing keys, decisions, action adapters, and availability. Threat sources include external attackers, malicious or careless insiders, compromised suppliers, failed data providers, model defects, and infrastructure failure.

3. Threat Register

ID	Threat	Impact	Primary controls
THR-001	Spoofed identity	Unauthorized access or false attribution	strong user/service authentication, session control, audit
THR-002	Tampered data or graph	Incorrect state or decision	hashes, signed manifests, provenance, quarantine, quality tests
THR-003	Model or threshold substitution	Silent behavior change	immutable registry, approval, integrity verification
THR-004	Evidence rewriting or deletion	Loss of accountability	append-only ledger, restricted writes, replication, backup
THR-005	Improper approval or social engineering	Unauthorized action	clear authority, dual approval, bounded actions, training
THR-006	Compromised dependency or update	Execution compromise	locked dependencies, offline scanning, signed releases
THR-007	File/schema injection	Code execution or corruption	sandboxed parsing, strict schemas, no dynamic evaluation
THR-008	Denial of service	Loss of monitoring or analysis	quotas, isolation, backpressure, redundancy
THR-009	Secret exposure	System compromise	secret manager, redaction, rotation, no secrets in evidence
THR-010	Unauthorized downstream action	Financial or operational harm	disabled adapters, governance, approval, kill switch, receipt reconciliation
THR-011	Replay or stale event	Incorrect temporal state	event IDs, sequence, timestamp, idempotency, replay protection
THR-012	Removable-media compromise	Air-gap malware or unsigned update	media control, offline scan, signature, dual custody
THR-013	Backup compromise	Exposure or irrecoverability	encryption, separate credentials, immutable copy, restore test
THR-014	Data/model poisoning	Biased or adversarial output	lineage, robust tests, benchmark, drift and poisoning review
THR-015	Audit evasion	Privileged action without accountability	protected audit path, separation of duty, gap alert

4. Identity and Access

- Named user and service identities.
- Least privilege by role, environment, data class, function, and authority.
- Time-bounded privilege for high-risk administration.
- Dual approval for release signing, action adapters, critical override, and destructive evidence policy.
- Immediate revocation and session invalidation during incident response.

5. Integrity and Cryptography

Sensitive communications and storage use deployment-approved encryption. Evidence objects and manifests are hashed. Releases, off-line updates, trust bundles, and material evidence are signed where supported. Signing keys are separated from ordinary application credentials.

6. Secure Release

1. Review requirement and threat changes.
2. Scan source, dependencies, secrets, and artifacts.
3. Run unit, laboratory, integration, abuse-case, and security tests.
4. Generate dependency and release manifest.
5. Sign and archive the approved package.
6. Stage deployment with a verified rollback target.
7. Verify integrity and monitoring after deployment.

7. Incident Response

Phase	Required action
Detect	alert on integrity, identity, audit, availability, data, model, or action anomaly
Triage	classify severity, scope, affected data/evidence/credentials/actions
Contain	disable adapter, revoke identity, isolate service, stop ingestion, or freeze release
Preserve	capture logs, evidence, hashes, timeline, and authorized forensic material
Eradicate	remove malicious artifact or configuration and close the path
Recover	restore verified release/data, validate evidence, reconcile actions
Review	document root cause, control failure, corrective action, and regression test

8. Security Verification

Authentication/authorization matrices, privilege escalation, parser fuzzing, tamper/signature failure, secret leakage, denial-of-service, quota isolation, backup theft/restore, action kill switch, and air-gap update rehearsals are mandatory before production.

Preserved limitations. Relationship 91 remains a failed baseline gate because its false-alarm rate exceeded the frozen ceiling. Relationship 12 retains a run-level evidence-availability limitation. Neither condition may be hidden by the aggregate pass count.

END OF CONTROLLED DOCUMENT 06

8Sphere Verification and Validation Plan

DOCUMENT 07Laboratory regressions, system verification, real-data validation, release gates, and independent review.

Document ID: 8S-VVP-001
Version: 1.0.0
Status: Engineering design baseline - not production authorization
Source: 8Sphere Relationships 1-100 laboratory evidence and professional expository note

Controlled-use notice. This document is an engineering design artifact. The laboratory program establishes internal mathematical and synthetic consistency under documented conditions. It does not independently establish real-world predictive performance or authorize automated financial or operational action.

1. Strategy

Verification determines whether the approved requirements and mathematics were implemented correctly. Validation determines whether the configured platform is suitable for its real intended use. Labs 1-100 are internal regression evidence, not a substitute for external validation.



2. Test Levels

Level	Purpose	Examples
L0 Static	detect schema, dependency, secret, and policy defects	lint, type, manifest
L1 Unit	verify function and error behavior	radius, S3 distance, hash, authorization
L2 Property/numerical	verify invariants and identities	bounds, norm, finite-difference agreement
L3 Laboratory regression	reproduce Relationships 1-100	frozen rules, seeds, evidence
L4 Integration	verify service, event, storage, and evidence contracts	state-to-risk, model-to-governance
L5 System/security	verify end-to-end resilience and threat controls	load, failover, backup, tamper, incident
L6 Domain validation	test real semantics, data, benchmark, costs, and outcomes	chronological holdout, external replication
L7 Pilot	test human workflow, alert load, action control, rollback	shadow and limited scope
L8 Continuous	monitor drift, reproducibility, incidents, and control health	scheduled regression and review

3. Laboratory Regression Baseline

Test	Rel.	Laboratory	Metric	Baseline result	Acceptance	Expected
TST-LAB-001	1	Five-coordinate base with S3 fiber	maximum integrity error	3.33067e-16 absolute error	< 1e-10	PASS
TST-LAB-002	2	Multiplicative weakest-link capacity	five-stress / one-stress capacity at 0.8	0.128502 ratio	< 0.20	PASS
TST-LAB-003	3	Boundary sensitivity	sensitivity at 0.99 / sensitivity at 0.50	12.2231 multiple	> 10	PASS
TST-LAB-004	4	Hard versus softened boundary	softened endpoint capacity	0.147135 normalized capacity	> 0 while hard endpoint = 0	PASS
TST-LAB-005	5	Base-dimension consistency	valid 8D constructions identified	2 count	= 2	PASS
TST-LAB-006	6	Stratified degenerating fiber space	dimension drop at first boundary	4 dimensions	= 4	PASS
TST-LAB-007	7	Non-injective projection aliasing	top-5 neighbor overlap	0.0556 fraction	< 0.50	PASS
TST-LAB-008	8	Signed directed coupling	negative relation share	0.165131 fraction	between 0.10 and 0.20	PASS
TST-LAB-009	9	Phase synchronization	order-parameter gain	0.952596 rho increase	> 0.20	PASS
TST-LAB-010	10	Logistic activation cascade	coupling scale for mean activation > 0.80	5 scale	finite threshold exists	PASS
TST-LAB-011	11	Shell-radius semantic direction	outer/inner ratio under $s^{1/3}$	2 ratio	= 2	PASS
TST-LAB-012	12	Integrated financial value test	8Sphere lead exceeds 2D rate	0.96 fraction	> 0.50	PASS
TST-LAB-013	13	Coordinate contribution decomposition	maximum log-radius reconstruction error	0 absolute log units	< 1e-12	PASS
TST-LAB-014	14	Unequal-stress concentration	allocation capacity within theoretical extrema	1 fraction	= 1.0	PASS
TST-LAB-015	15	Coordinate elasticity	maximum finite-difference relative error	1.09424e-07 fraction	< 1e-6	PASS
TST-LAB-016	16	Cross-coordinate derivatives	maximum mixed-derivative absolute error	1.10018e-07 capacity per coordinate squared	< 1e-6	PASS
TST-LAB-017	17	Curvature toward collapse	curvature magnitude at 0.97 / at 0.50	45.3482 multiple	> 10 and curvature negative	PASS
TST-LAB-018	18	Weighted-coordinate capacity	maximum weight-derivative absolute error	5.10211e-10 log-capacity per weight	< 1e-8	PASS
TST-LAB-019	19	S3 angular distance	maximum metric or chord-identity error	2.30371e-15 absolute error	< 1e-10	PASS
TST-LAB-020	20	Prototype base-fiber coupling	maximum norm or reversal error	3.34509e-16 absolute error	< 1e-10 and monotonic angle	PASS
TST-LAB-021	21	Path dependence and holonomy	small-loop log-log angle/area slope	1.00078 slope	between 0.8 and 1.2 with nonzero loop angle	PASS
TST-LAB-022	22	Spectral cascade threshold	median log threshold / log spectral-radius slope	-1 slope	within 0.02 of -1	PASS
TST-LAB-023	23	Synchronization-activation association	pooled Spearman association	0.956237 correlation	> 0.90	PASS
TST-LAB-024	24	Hysteresis and recovery	median activation-recovery loop area	0.0315074 activation × coupling scale	> 0.01 in at least 90% of networks	PASS
TST-LAB-025	25	Signed-network balance and antagonistic clusters	maximum empirical-versus-analytic triangle imbalance error	0.00689262 fraction	< 0.02 and zero imbalance at zero sign noise	PASS
TST-LAB-026	26	Centrality versus systemic influence	median top-five overlap between immediate strength and high-coupling influence	0.6 fraction	< 0.90 with resolvent reconstruction error < 1e-10	PASS
TST-LAB-027	27	Projection dimension from 1D through 7D	increase in mean top-ten neighbor overlap from 1D to 7D	0.70729 fraction	> 0.60 and both distance and neighborhood metrics strictly increase	PASS
TST-LAB-028	28	Projection reconstruction error	maximum PCA residual-formula error	7.77156e-16 mean-squared error	< 1e-12 with zero random-subspace optimality violations	PASS
TST-LAB-029	29	Noise sensitivity and missing-coordinate robustness	rank correlation at sigma 0.05 and 10% missingness	0.860487 correlation	> 0.85 with exact clean-data baseline	PASS
TST-LAB-030	30	Boundary recovery time	analytic-versus-simulated recovery-step mismatch rate	0 fraction	= 0	PASS
TST-LAB-031	31	Shock propagation speed	fraction of nodes whose first-arrival time differs from graph distance	0 fraction	= 0	PASS
TST-LAB-032	32	Regime switching	median hidden-regime decoding accuracy	1 fraction	> 0.95 with median transition F1 > 0.90	PASS
TST-LAB-033	33	Parameter identifiability	median relative weight error under strong excitation	0.000119653 fraction	< 0.005 and weak-excitation error > 10× strong-excitation error	PASS
TST-LAB-034	34	False-alert cost and warning utility	absolute difference between empirical and Bayes cost threshold	0.00733333 probability	< 0.03 and optimized cost below both always/never alert policies	PASS
TST-LAB-035	35	Calibration against realized probabilities	expected calibration error of the calibrated probability model	0.00290469 fraction	< 0.01 and calibrated model has the lowest Brier score	PASS
TST-LAB-036	36	Walk-forward and out-of-sample stability	minimum chronological out-of-sample AUC	0.733063 AUC	> 0.70 with median train-test gap < 0.08 and fold AUC SD < 0.04	PASS
TST-LAB-037	37	Effective dimensionality	Spearman anisotropy-dimension correlation	-1 correlation	rho < -0.98	PASS
TST-LAB-038	38	Local Jacobian conditioning	Boundary/interior condition ratio	19.5472 multiple	ratio > 10 and rho > 0.99	PASS

Test	Rel.	Laboratory	Metric	Baseline result	Acceptance	Expected
TST-LAB-039	39	S ³ geodesic-chord equivalence	Maximum identity error	1.83187e-15 absolute error	error < 1e-12	PASS
TST-LAB-040	40	Capacity level-set volume	Monotonicity violations	0 count	zero violations	PASS
TST-LAB-041	41	Coordinate-contribution entropy	Spearman HHI-entropy correlation	-0.998421 correlation	rho < -0.95	PASS
TST-LAB-042	42	Base-fiber mutual information	Empirical/analytic maximum error	0.0168594 nats	error < 0.03 and monotonic rho > 0.98	PASS
TST-LAB-043	43	Capacity-surface curvature	Maximum Hessian relative error	1.27788e-07 fraction	error < 0.002	PASS
TST-LAB-044	44	Stress-cluster persistence	Two-cluster persistence span	0.928571 fraction of thresholds	persistence > 0.30	PASS
TST-LAB-045	45	Lyapunov contraction	Estimated contraction exponent	-0.223192 log-distance per step	slope < -0.05	PASS
TST-LAB-046	46	Critical slowing down	Maximum recovery-time mismatch	0 steps	mismatch = 0 and rho > 0.99	PASS
TST-LAB-047	47	Basin-of-attraction boundary	Estimated basin boundary	0 state units	boundary < 0.01	PASS
TST-LAB-048	48	Delay-induced oscillation	Peak delayed/no-delay oscillation ratio	57.3042 multiple	ratio > 5	PASS
TST-LAB-049	49	Damping ratio and overshoot	Maximum overshoot error	2.56553e-07 fraction	error < 0.002	PASS
TST-LAB-050	50	Minimum control-energy scaling	Maximum analytic/constructed energy error	5.55112e-17 energy	error < 1e-12 and terminal x < 1e-12	PASS
TST-LAB-051	51	Resonance under periodic forcing	Peak-frequency error	0.00121019 frequency units	error < 0.01	PASS
TST-LAB-052	52	Adaptive feedback stabilization	RMS-state reduction	0.998713 fraction	reduction > 0.90	PASS
TST-LAB-053	53	k-core depth and cascade reach	Spearman core-cascade correlation	0.922099 correlation	rho > 0.65	PASS
TST-LAB-054	54	Community modularity and containment	Spearman modularity-containment correlation	0.844845 correlation	rho > 0.75	PASS
TST-LAB-055	55	Edge betweenness and contagion bridges	Connectivity reduction advantage	0.25 fraction	advantage > 0.20	PASS
TST-LAB-056	56	Multiplex-layer coupling	Coupling-threshold Spearman correlation	-1 correlation	rho < -0.95	PASS
TST-LAB-057	57	Assortativity and shock amplification	Assortativity-amplification correlation	0.921193 correlation	rho > 0.70	PASS
TST-LAB-058	58	Path redundancy and resilience	Maximum connectivity error	0.00157714 fraction	error < 0.015	PASS
TST-LAB-059	59	Network percolation threshold	Estimated-threshold error	0.114286 mean-degree units	error < 0.30	PASS
TST-LAB-060	60	Targeted versus random node removal	Mean targeted-removal disadvantage	0.926556 fraction	difference > 0.20	PASS
TST-LAB-061	61	Fisher information and excitation	Maximum Hessian relative error	1.0504e-06 fraction	error < 0.001	PASS
TST-LAB-062	62	Bias-variance tradeoff	High-degree/minimum MSE ratio	408.648 multiple	interior optimum and ratio > 1.2	PASS
TST-LAB-063	63	Regularization path	Lambda-norm Spearman correlation	-1 correlation	rho < -0.99	PASS
TST-LAB-064	64	Feature collinearity and coefficient instability	Correlation-collinearity variance correlation	0.948872 correlation	rho > 0.94 and prediction ratio < 2	PASS
TST-LAB-065	65	Sample complexity	Log-log error slope	-0.620605 slope	-0.70 < slope < -0.30	PASS
TST-LAB-066	66	Domain-shift sensitivity	Shift-error Spearman correlation	0.997059 correlation	rho > 0.95	PASS
TST-LAB-067	67	Conformal prediction coverage	Maximum absolute coverage error	0.0135714 fraction	error < 0.025	PASS
TST-LAB-068	68	Ensemble diversity benefit	Diversity-improvement correlation	1 correlation	rho > 0.98	PASS
TST-LAB-069	69	Expected shortfall versus capacity radius	Radius-ES Spearman correlation	-1 correlation	rho < -0.99 and max error < 0.03	PASS
TST-LAB-070	70	Tail dependence beyond correlation	Student-t/Gaussian tail-dependence ratio	1.82267 multiple	ratio > 1.5	PASS
TST-LAB-071	71	Diversification under correlation	Maximum variance error	0.00783185 variance units	error < 0.01 and monotonic rho > 0.99	PASS
TST-LAB-072	72	Kelly sizing under uncertainty	Mean shrinkage growth advantage	0.00230862 log-growth per bet	advantage > 0	PASS
TST-LAB-073	73	Drawdown-duration dynamics	Drift-duration Spearman correlation	-0.973422 correlation	rho < -0.90	PASS
TST-LAB-074	74	Risk-budget attribution	Maximum additivity error	8.88178e-16 variance units	error < 1e-10	PASS
TST-LAB-075	75	Transaction-cost break-even	Grid break-even error	1.7229e-05 cost units	error < 0.00005	PASS
TST-LAB-076	76	Liquidity and square-root slippage	Estimated log-log slope error	0.00216531 slope	error < 0.03	PASS
TST-LAB-077	77	Outlier influence and robust estimation	OLS/Huber error ratio at 20% contamination	12.9524 multiple	ratio > 3	PASS
TST-LAB-078	78	Heavy-tail robustness	Mean/MoM RMSE ratio	1.71291 multiple	ratio > 1.2	PASS
TST-LAB-079	79	Adversarial coordinate perturbation	Adversarial/positive-random mean damage ratio	5.06971 multiple	ratio > 2	PASS
TST-LAB-080	80	Label-noise attenuation and ranking resilience	Noise-coefficient-norm Spearman correlation	-1 correlation	rho < -0.98 and minimum AUC > 0.70	PASS
TST-LAB-081	81	Delayed-data degradation	Delay-AUC Spearman correlation	-1 correlation	rho < -0.98	PASS
TST-LAB-082	82	Asynchronous-sampling attenuation	Window-correlation Spearman correlation	1 correlation	rho > 0.90	PASS

Test	Rel.	Laboratory	Metric	Baseline result	Acceptance	Expected
TST-LAB-083	83	Coordinate quantization precision	Log2 RMSE slope per bit	-1.01066 slope	-1.15 < slope < -0.85	PASS
TST-LAB-084	84	Model-version reproducibility	Drifted-version RMSE	0.217591 prediction units	exact error < 1e-12 and drift RMSE > 0.05	PASS
TST-LAB-085	85	Directional Granger predictability	Forward-direction p-value	0 probability	p_xy < 0.01 and p_yx > 0.05	PASS
TST-LAB-086	86	Intervention-response recovery	Maximum intervention-effect error	0 outcome units	error < 1e-12	PASS
TST-LAB-087	87	Counterfactual structural consistency	Maximum counterfactual identity error	1.33227e-15 outcome units	error < 1e-12	PASS
TST-LAB-088	88	Confounding and adjustment	Error reduction at strongest confounding	0.976798 fraction	reduction > 0.90	PASS
TST-LAB-089	89	Lead-lag estimation	Exact-lag recovery rate	1 fraction	accuracy > 0.95	PASS
TST-LAB-090	90	Future-regime leakage in validation	Shuffled-validation optimism	0.843946 AUC	optimism > 0.03	PASS
TST-LAB-091	91	Change-point detection	Median detection delay	9 steps	median delay < 12 and false-alarm rate < 0.05	FAIL
TST-LAB-092	92	Forecast-horizon decay	Maximum R ² -law error	0.0049466 fraction	error < 0.01 and monotonic rho < -0.99	PASS
TST-LAB-093	93	Decision-threshold stability	Bootstrap threshold IQR	0.0217877 probability	IQR < 0.025 and median within 0.02 of theory	PASS
TST-LAB-094	94	Benchmark-superiority gate	Holdout AUC gain	0.119727 AUC	gain > 0.08	PASS
TST-LAB-095	95	Cost-adjusted out-of-sample performance	Net annualized Sharpe	1.27651 Sharpe ratio	net Sharpe > 0.5 and cumulative net P&L > 0	PASS
TST-LAB-096	96	Integrated stress-scenario composition	Maximum scenario-composition error	4.63185e-12 log-capacity units	error < 1e-10	PASS
TST-LAB-097	97	Predictive-uncertainty decomposition	Maximum Monte Carlo decomposition error	0.0043404 variance units	error < 0.02	PASS
TST-LAB-098	98	Human-model decision fusion	Fusion AUC gain over best component	0.028204 AUC	gain > 0.015	PASS
TST-LAB-099	99	Cross-seed reproducibility	Across-seed coefficient of variation	0.00499983 fraction	CV < 0.01 and exact rerun error = 0	PASS
TST-LAB-100	100	Integrated 8Sphere validation gate	Integrated evidence score	0.952191 score from 0 to 1	score >= 0.90, minimum category >= 0.85, order invariant	PASS

4. Relationship 91 Defect

The baseline change-point detector achieved median delay 9 but a 5.9% false-alarm rate against a 5% ceiling. The expected baseline verdict remains **FAIL**. Any successor must use a new protocol and may not overwrite the original evidence.

5. Real-Data Validation

1. Define intended and prohibited uses, decision owner, and harm model.
2. Freeze coordinate, fiber, graph, target, missingness, time, and cost definitions.
3. Select simple and domain-standard benchmarks before observing holdout performance.
4. Use chronological partitions with an untouched final holdout and external replication when feasible.
5. Include latency, revision, cost, slippage, availability, and operational constraints.
6. Test calibration, discrimination, utility, robustness, shift, subgroups, and failure cases.
7. Obtain independent review of code, data lineage, metrics, and claims.
8. Run shadow mode before advisory or action-enabled pilot.

6. Reliability and Human Factors

Performance, workload isolation, event ordering, failover, backup/restore, evidence growth, long-running soak, status comprehension, alert workload, alternative comparison, override, update/rollback, and auditor reconstruction are tested before production.

7. Release Gate

Gate	Required verdict
Requirement traceability	Complete
Laboratory regression	99 PASS / 1 expected FAIL disclosed
Numerical conformance	Pass
Integration/evidence integrity	Pass
Security/recovery	Pass
Domain validation	Pass for intended use
Pilot/human factors	Pass
Governance	Approved with conditions recorded

8Sphere Deployment and Operations Manual

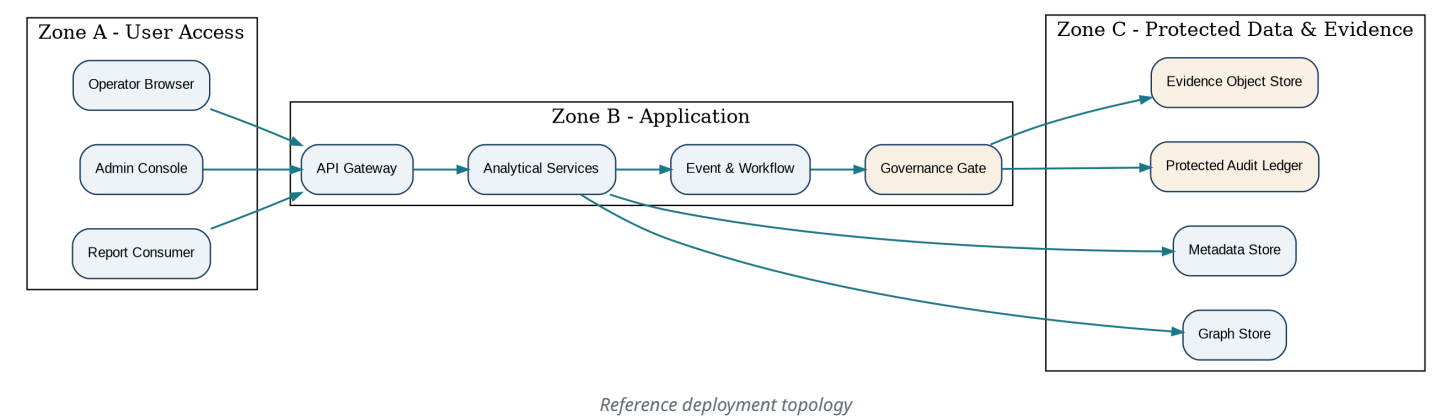
DOCUMENT 08

Installation, configuration, monitoring, backup, recovery, upgrades, rollback, and troubleshooting.

Document ID: 8S-DOM-001
Version: 1.0.0
Status: Engineering design baseline - not production authorization
Source: 8Sphere Relationships 1-100 laboratory evidence and professional expository note

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1. Deployment Profiles



Profile	Use	Characteristics
DEV-SINGLE	development and unit test	single node, synthetic data, no production adapters
LAB-OFFLINE	reproducible laboratory	offline/air-gapped, signed package, fixed seeds, evidence export
OPS-PRIVATE	private monitoring and advisory	separated zones, enterprise identity, backup, alerts, no action by default
HA-PROD	approved high availability	redundant services/stores, failover, protected keys, controlled adapters

2. Preinstallation

Confirm deployment profile, data classification, hardware, time source, identity and signing plan, storage capacity, network/firewall, offline update path, approved release and rollback packages, and a tested backup destination.

3. Installation

1. Create service identities, protected directories, and secret locations.
2. Import the trust bundle.
3. Verify release signature, manifest, hashes, and compatibility.
4. Install from the approved offline package.
5. Initialize metadata, graph, evidence, audit, and registry stores.
6. Apply environment configuration separately from executable release.
7. Run startup conformance, smoke laboratories, evidence write/read, and authentication tests.
8. Record installation evidence and approve activation.

4. Configuration Domains

Domain	Examples	Approval
Platform	addresses, quotas, workers, storage	operations
Security	roles, certificates, keys, sessions, export	security
Analytical	tolerances, normalization, simulation limits	technical authority and validation
Domain	coordinate and fiber semantics, target, costs	domain owner and validation
Model	features, calibration, thresholds	model-risk authority
Workflow	severity, escalation, action adapter	operations and governance

Domain	Examples	Approval
Retention	classes, holds, deletion	data owner and applicable legal/security

5. Startup and Shutdown

Operation	Sequence
Startup	stores → audit/evidence → identity → registry/config → event/workflow → analytics → API → Observatory → adapters last
Readiness	health, storage, time, trust, release hash, evidence commit, synthetic evaluation
Graceful shutdown	disable new work/actions → drain → checkpoint → commit evidence → stop UI/API/services → stores last
Emergency	kill action adapters → isolate → preserve evidence/audit → incident process

6. Monitoring

Monitor availability, latency, throughput, queue depth, worker saturation, data freshness, missingness, schema rejects, drift, calibration, coverage, benchmark gap, evidence commit, signature failures, audit continuity, alert age, overrides, backups, and rollback readiness.

7. Backup and Restore

Back up metadata, graph, registry, evidence, audit, configuration, and recovery material. Maintain an isolated or immutable critical copy. Verify hashes and catalogs. Restore first to isolation, verify release and evidence integrity, run representative computations, and record recovery evidence before return to service.

8. Update and Rollback

Verify signed package and compatibility, review regressions and security, create backup/checkpoint, deploy to staging, canary the change, verify health and evidence, and roll back immediately if exit criteria fail. Failed-update evidence is preserved.

9. Troubleshooting

Symptom	Checks	Response
State rejected	schema, bounds, units, definitions, norm, missingness	correct source/definition; do not silently clip
Capacity instability	boundary, log-domain evaluation, conditioning	use stable method and label softened analysis
Simulation nonconvergence	law, step, saturation, resources, delay	fail run and preserve checkpoint/evidence
Evidence commit failure	store, permissions, quota, hash	block authoritative completion
Alert storm	data anomaly, threshold, dedup, hysteresis, drift	contain workload; approved suppression only
Model degradation	shift, delay, leakage, feature/schema, calibration	degrade or withdraw and revalidate
Graph mismatch	snapshot/hash, normalization, direction/layer	recompute exact version
Authorization denied	identity, role, environment, approval	correct through approved access process
Update failed	integrity, migration, compatibility	rollback and open defect

10. Disaster Recovery

Recovery priority is evidence/audit integrity, identity, configuration/registry, metadata, graph, analytical services, Observatory, and action adapters last. Reconcile all pending or downstream actions after recovery.

Preserved limitations. Relationship 91 remains a failed baseline gate because its false-alarm rate exceeded the frozen ceiling. Relationship 12 retains a run-level evidence-availability limitation. Neither condition may be hidden by the aggregate pass count.

END OF CONTROLLED DOCUMENT 08

8Sphere Governance and Model-Risk Framework

DOCUMENT 09

Claim classes, authority separation, model risk, approvals, exceptions, and ongoing oversight.

Document ID: 8S-GMR-001

Version: 1.0.0

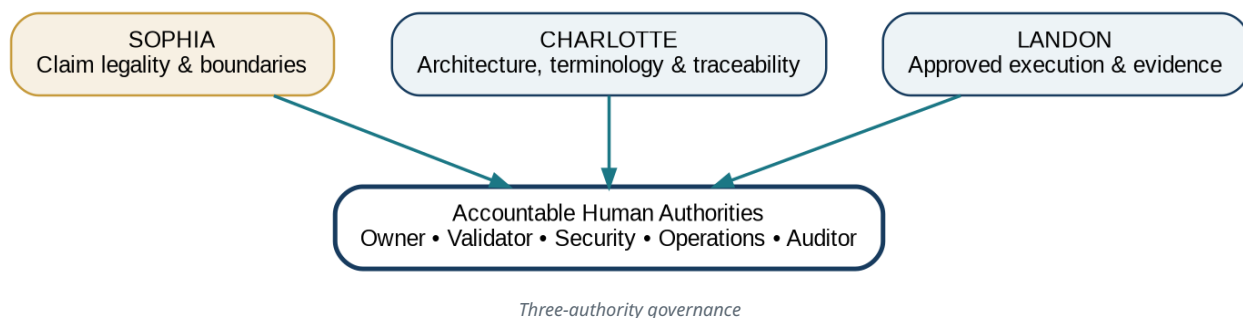
Status: Engineering design baseline - not production authorization

Source: 8Sphere Relationships 1-100 laboratory evidence and professional expository note

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1. Objective

Define decision rights, separation of duties, claim boundaries, model lifecycle, approval gates, exceptions, monitoring, and accountability.



2. Authority Model

Authority	Mandate	Cannot do alone
SOPHIA	claim legality, semantic limits, action class	execute tests, change evidence, or approve own interpretation
CHARLOTTE	terminology, units, architecture, schemas, traceability, documentation	authorize unsupported claims or deployment
LONDON	approved computation, testing, monitoring, artifact generation	change frozen rules or approve own execution
System Owner	purpose, scope, resources, risk acceptance	independently validate own system
Domain Owner	domain semantics, costs, targets, interpretation	waive integrity or security
Independent Validator	challenge and approve/reject validation	self-approve implementation
Security Authority	security design and residual risk	approve analytical claims
Operations Authority	deployment, recovery, support readiness	change model semantics
Auditor	assess evidence and controls	operate the system under audit

3. Claim Taxonomy

Class	Meaning	Permitted statement
Mathematical	follows from stated definitions or identity	implementation reproduces the property within tolerance
Synthetic	observed in controlled generated data or prototype dynamics	controlled experiment produced the result
Empirical	observed in governed real-world data	study found the result in the specified data and period
Predictive	validated estimate for unseen outcomes	model achieved the specified out-of-sample result subject to limits
Advisory	recommendation requiring human decision	system recommends; authorized human decides
Automated action	preauthorized bounded machine action	action executed under approved policy and controls

4. Lifecycle

Proposal → intended-use and risk tier → data/semantics → method and implementation → developer tests → independent validation → approval and release → monitoring → periodic review/change/suspension/retirement/archive.

5. Risk Tiers

Tier	Description	Minimum governance
T0 Research	sandbox, synthetic/exploratory, no operational use	evidence and claim label; no adapter
T1 Informational	descriptive monitoring, low consequence	owner, data quality, audit, user guidance
T2 Advisory	material human decision support	independent validation, benchmark, uncertainty, human authority
T3 Controlled automation	bounded and reversible actions	enhanced validation, security, dual approval, kill switch, pilot
T4 High consequence	major financial, safety, legal, or public impact	executive risk acceptance and continuous assurance

6. Approval Gates

Gate	Required authority and evidence
Design baseline	system owner, architecture/conformance, security review, validation plan
Model registration	domain owner, independent validation, SOPHIA claim, CHARLOTTE documenta- tion
Production release	owner, validation, security, operations, signed evidence
Threshold or policy change	domain/model owner, validation, governance, effective date
Action adapter	owner, security, operations, risk acceptance, kill-switch rehearsal
Exception	risk owner, rationale, compensating control, expiration, monitoring
Retirement	owner, operations, retention and transition plan

7. Known Limitations

- **Relationship 91:** change-point detector failed the false-alarm gate and cannot support autonomous action.
- **Relationship 12:** original run-level CSV was not present; authoritative summaries disclose the evidence limitation.
- Laboratory success is not real-world validation.

8. Monitoring Cadence

Cadence	Review
Continuous	security, availability, data freshness, evidence integrity, critical actions
Daily	failed runs, stale data, high alerts, overrides, backup
Monthly	model/threshold health, calibration, drift, alert burden, incidents, exceptions
Quarterly	risk inventory, access, resilience, restore, releases, governance metrics
Annual/material change	full intended-use, validation, security, documentation, and retirement review

9. Exceptions

Every exception records requirement, rationale, risk, compensating control, owner, approver, effective period, monitoring, expiration, and closure evidence. Exceptions cannot rewrite historical laboratory results or evidence.

Preserved limitations. Relationship 91 remains a failed baseline gate because its false-alarm rate exceeded the frozen ceiling. Relationship 12 retains a run-level evidence-availability limitation. Neither condition may be hidden by the aggregate pass count.

END OF CONTROLLED DOCUMENT 09

8Sphere Lab-to-System Traceability Matrix

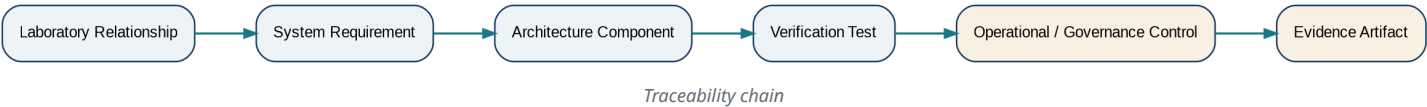
DOCUMENT 10 Direct mapping from Relationships 1-100 to requirements, components, tests, controls, and evidence.

Document ID: 8S-LTM-001
Version: 1.0.0
Status: Engineering design baseline - not production authorization
Source: 8Sphere Relationships 1-100 laboratory evidence and professional expository note

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1. Purpose

The matrix provides the bidirectional bridge from every laboratory relationship to a requirement, component, verification test, control, evidence source, and baseline status.



2. Control IDs

Control	Purpose
CTRL-NUM-001	bounds, numerical tolerance, conditioning, and nonconvergence
CTRL-EVD-001	immutable evidence, hashes, versions, seed, environment, approvals

Control	Purpose
CTRL-VAL-001	frozen validation, chronology, benchmark, calibration, shift, robustness
CTRL-CHG-001	versioned change, regression, approval, release, rollback
CTRL-GOV-001	claim class, known limitations, human authority, permitted action
CTRL-SEC-001	identity, authorization, integrity, isolation, audit, incident

3. Relationship Matrix

Rel.	Laboratory	Family	Components	Requirements	Test / controls	Evidence	Status	Baseline result
1	Five-coordinate base with S3 fiber	Mathematical foundation	CMP-KRN, CMP-STA	REQ-F-001, REQ-F-002, REQ-F-003, REQ-F-004, REQ-Q-002	TST-LAB-001 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_01_*.csv / evidence JSON	PASS	maximum integrity error: 3.33067e-16 absolute error
2	Multiplicative weak-link capacity	Mathematical foundation	CMP-KRN, CMP-STA	REQ-F-001, REQ-F-002, REQ-F-003, REQ-F-004, REQ-Q-002	TST-LAB-002 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_02_*.csv / evidence JSON	PASS	five-stress / one-stress capacity at 0.8: 0.128502 ratio
3	Boundary sensitivity	Mathematical foundation	CMP-KRN, CMP-STA	REQ-F-001, REQ-F-002, REQ-F-003, REQ-F-004, REQ-Q-002	TST-LAB-003 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_03_*.csv / evidence JSON	PASS	sensitivity at 0.99 / sensitivity at 0.50: 12.2231 multiple
4	Hard versus softened boundary	Mathematical foundation	CMP-KRN, CMP-STA	REQ-F-001, REQ-F-002, REQ-F-003, REQ-F-004, REQ-Q-002	TST-LAB-004 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_04_*.csv / evidence JSON	PASS	softened endpoint capacity: 0.147135 normalized capacity
5	Base-dimension consistency	Mathematical foundation	CMP-KRN, CMP-STA	REQ-F-001, REQ-F-002, REQ-F-003, REQ-F-004, REQ-Q-002	TST-LAB-005 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_05_*.csv / evidence JSON	PASS	valid 8D constructions identified: 2 count
6	Stratified degenerating fiber space	Mathematical foundation	CMP-KRN, CMP-STA	REQ-F-001, REQ-F-002, REQ-F-003, REQ-F-004, REQ-Q-002	TST-LAB-006 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_06_*.csv / evidence JSON	PASS	dimension drop at first boundary: 4 dimensions
7	Non-injective projection aliasing	Mathematical foundation	CMP-KRN, CMP-STA	REQ-F-001, REQ-F-002, REQ-F-003, REQ-F-004, REQ-Q-002	TST-LAB-007 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_07_*.csv / evidence JSON	PASS	top-5 neighbor overlap: 0.0556 fraction
8	Signed directed coupling	Coupling and integrated behavior	CMP-GPH, CMP-DYN, CMP-RSK, CMP-SIM	REQ-F-007, REQ-F-009, REQ-F-015, REQ-F-018	TST-LAB-008 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_08_*.csv / evidence JSON	PASS	negative relation share: 0.165131 fraction
9	Phase synchronization	Coupling and integrated behavior	CMP-GPH, CMP-DYN, CMP-RSK, CMP-SIM	REQ-F-007, REQ-F-009, REQ-F-015, REQ-F-018	TST-LAB-009 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_09_*.csv / evidence JSON	PASS	order-parameter gain: 0.952596 rho increase
10	Logistic activation cascade	Coupling and integrated behavior	CMP-GPH, CMP-DYN, CMP-RSK, CMP-SIM	REQ-F-007, REQ-F-009, REQ-F-015, REQ-F-018	TST-LAB-010 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_10_*.csv / evidence JSON	PASS	coupling scale for mean activation > 0.80: 5 scale
11	Shell-radius semantic direction	Coupling and integrated behavior	CMP-GPH, CMP-DYN, CMP-RSK, CMP-SIM	REQ-F-007, REQ-F-009, REQ-F-015, REQ-F-018	TST-LAB-011 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_11_*.csv / evidence JSON	PASS	outer/inner ratio under $s^{1/3}$: 2 ratio
12	Integrated financial value test	Coupling and integrated behavior	CMP-GPH, CMP-DYN, CMP-RSK, CMP-SIM	REQ-F-007, REQ-F-009, REQ-F-015, REQ-F-018	TST-LAB-012 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_12_*.csv / evidence JSON	PASS	8Sphere lead exceeds 2D rate: 0.96 fraction
13	Coordinate contribution decomposition	Differential geometry and fiber dynamics	CMP-KRN, CMP-STA	REQ-F-002, REQ-F-003, REQ-F-006, REQ-Q-002	TST-LAB-013 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_13_*.csv / evidence JSON	PASS	maximum log-radius reconstruction error: 0 absolute log units
14	Unequal-stress concentration	Differential geometry and fiber dynamics	CMP-KRN, CMP-STA	REQ-F-002, REQ-F-003, REQ-F-006, REQ-Q-002	TST-LAB-014 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_14_*.csv / evidence JSON	PASS	allocation capacity within theoretical extrema: 1 fraction
15	Coordinate elasticity	Differential geometry and fiber dynamics	CMP-KRN, CMP-STA	REQ-F-002, REQ-F-003, REQ-F-006, REQ-Q-002	TST-LAB-015 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_15_*.csv / evidence JSON	PASS	maximum finite-difference relative error: 1.09424e-07 fraction
16	Cross-coordinate derivatives	Differential geometry and fiber dynamics	CMP-KRN, CMP-STA	REQ-F-002, REQ-F-003, REQ-F-006, REQ-Q-002	TST-LAB-016 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_16_*.csv / evidence JSON	PASS	maximum mixed-derivative absolute error: 1.10018e-07 capacity per co-ordinate squared
17	Curvature toward collapse	Differential geometry and fiber dynamics	CMP-KRN, CMP-STA	REQ-F-002, REQ-F-003, REQ-F-006, REQ-Q-002	TST-LAB-017 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_17_*.csv / evidence JSON	PASS	curvature magnitude at 0.97 / at 0.50: 45.3482 multiple
18	Weighted-coordinate capacity	Differential geometry and fiber dynamics	CMP-KRN, CMP-STA	REQ-F-002, REQ-F-003, REQ-F-006, REQ-Q-002	TST-LAB-018 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_18_*.csv / evidence JSON	PASS	maximum weight-derivative absolute error: 5.10211e-10 log-capacity per weight
19	S3 angular distance	Differential geometry and fiber dynamics	CMP-KRN, CMP-STA	REQ-F-002, REQ-F-003, REQ-F-006, REQ-Q-002	TST-LAB-019 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_19_*.csv / evidence JSON	PASS	maximum metric or chord-identity error: 2.30371e-15 absolute error
20	Prototype base-fiber coupling	Differential geometry and fiber dynamics	CMP-STA, CMP-GPH, CMP-DYN, CMP-SIM	REQ-F-006, REQ-F-008, REQ-F-009, REQ-F-018	TST-LAB-020 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_20_*.csv / evidence JSON	PASS	maximum norm or reversal error: 3.34509e-16 absolute error
21	Path dependence and holonomy	Differential geometry and fiber dynamics	CMP-STA, CMP-GPH, CMP-DYN, CMP-SIM	REQ-F-006, REQ-F-008, REQ-F-009, REQ-F-018	TST-LAB-021 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_21_*.csv / evidence JSON	PASS	small-loop log-log angle/area slope: 1.00078 slope
22	Spectral cascade threshold	Network transitions and influence	CMP-STA, CMP-GPH, CMP-DYN, CMP-SIM	REQ-F-006, REQ-F-008, REQ-F-009, REQ-F-018	TST-LAB-022 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_22_*.csv / evidence JSON	PASS	median log threshold / log spectral-radius slope: -1 slope
23	Synchronization-activation association	Network transitions and influence	CMP-STA, CMP-GPH, CMP-DYN, CMP-SIM	REQ-F-006, REQ-F-008, REQ-F-009, REQ-F-018	TST-LAB-023 / CTRL-EVD-001; CTRL-CHG-001	relation-ship_23_*.csv / evidence JSON	PASS	pooled Spearman association: 0.956237 correlation

Rel.	Laboratory	Family	Components	Requirements	Test / controls	Evidence	Status	Baseline result
24	Hysteresis and re-recovery	Network transitions and influence	CMP-STA, CMP-GPH, CMP-DYN, CMP-SIM	REQ-F-006, REQ-F-008, REQ-F-009, REQ-F-018	TST-LAB-024 / CTRL-EVD-001; CTRL-CHG-001	relationship_24_*.csv / evidence JSON	PASS	median activation-recovery loop area: 0.0315074 activation × coupling scale
25	Signed-network balance and antagonistic clusters	Network transitions and influence	CMP-KRN, CMP-GPH, CMP-DYN, CMP-LRN	REQ-F-004, REQ-F-008, REQ-F-009, REQ-F-016	TST-LAB-025 / CTRL-EVD-001; CTRL-CHG-001	relationship_25_*.csv / evidence JSON	PASS	maximum empirical-versus-analytic triangle imbalance error: 0.00689262 fraction
26	Centrality versus systemic influence	Network transitions and influence	CMP-KRN, CMP-GPH, CMP-DYN, CMP-LRN	REQ-F-004, REQ-F-008, REQ-F-009, REQ-F-016	TST-LAB-026 / CTRL-EVD-001; CTRL-CHG-001	relationship_26_*.csv / evidence JSON	PASS	median top-five overlap between immediate strength and high-coupling influence: 0.6 fraction
27	Projection dimension from 1D through 7D	Projection, robustness, and timing	CMP-KRN, CMP-GPH, CMP-DYN, CMP-LRN	REQ-F-004, REQ-F-008, REQ-F-009, REQ-F-016	TST-LAB-027 / CTRL-EVD-001; CTRL-CHG-001	relationship_27_*.csv / evidence JSON	PASS	increase in mean top-ten neighbor overlap from 1D to 7D: 0.70729 fraction
28	Projection reconstruction error	Projection, robustness, and timing	CMP-KRN, CMP-GPH, CMP-DYN, CMP-LRN	REQ-F-004, REQ-F-008, REQ-F-009, REQ-F-016	TST-LAB-028 / CTRL-EVD-001; CTRL-CHG-001	relationship_28_*.csv / evidence JSON	PASS	maximum PCA residual-formula error: 7.77156e-16 mean-squared error
29	Noise sensitivity and missing-coordinate robustness	Projection, robustness, and timing	CMP-KRN, CMP-GPH, CMP-DYN, CMP-LRN	REQ-F-004, REQ-F-008, REQ-F-009, REQ-F-016	TST-LAB-029 / CTRL-EVD-001; CTRL-CHG-001	relationship_29_*.csv / evidence JSON	PASS	rank correlation at sigma 0.05 and 10% missingness: 0.860487 correlation
30	Boundary recovery time	Projection, robustness, and timing	CMP-KRN, CMP-GPH, CMP-DYN, CMP-LRN	REQ-F-004, REQ-F-008, REQ-F-009, REQ-F-016	TST-LAB-030 / CTRL-EVD-001; CTRL-CHG-001	relationship_30_*.csv / evidence JSON	PASS	analytic-versus-simulated recovery-step mismatch rate: 0 fraction
31	Shock propagation speed	Projection, robustness, and timing	CMP-KRN, CMP-GPH, CMP-DYN, CMP-LRN	REQ-F-004, REQ-F-008, REQ-F-009, REQ-F-016	TST-LAB-031 / CTRL-EVD-001; CTRL-CHG-001	relationship_31_*.csv / evidence JSON	PASS	fraction of nodes whose first-arrival time differs from graph distance: 0 fraction
32	Regime switching	Statistical validation	CMP-LRN, CMP-EVD, CMP-GOV	REQ-F-012, REQ-F-013, REQ-F-014, REQ-F-018, REQ-G-001	TST-LAB-032 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_32_*.csv / evidence JSON	PASS	median hidden-regime decoding accuracy: 1 fraction
33	Parameter identifiability	Statistical validation	CMP-LRN, CMP-EVD, CMP-GOV	REQ-F-012, REQ-F-013, REQ-F-014, REQ-F-018, REQ-G-001	TST-LAB-033 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_33_*.csv / evidence JSON	PASS	median relative weight error under strong excitation: 0.000119653 fraction
34	False-alert cost and warning utility	Statistical validation	CMP-LRN, CMP-EVD, CMP-GOV	REQ-F-012, REQ-F-013, REQ-F-014, REQ-F-018, REQ-G-001	TST-LAB-034 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_34_*.csv / evidence JSON	PASS	absolute difference between empirical and Bayes cost threshold: 0.00733333 probability
35	Calibration against realized probabilities	Statistical validation	CMP-LRN, CMP-EVD, CMP-GOV	REQ-F-012, REQ-F-013, REQ-F-014, REQ-F-018, REQ-G-001	TST-LAB-035 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_35_*.csv / evidence JSON	PASS	expected calibration error of the calibrated probability model: 0.00290469 fraction
36	Walk-forward and out-of-sample stability	Statistical validation	CMP-LRN, CMP-EVD, CMP-GOV	REQ-F-012, REQ-F-013, REQ-F-014, REQ-F-018, REQ-G-001	TST-LAB-036 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_36_*.csv / evidence JSON	PASS	minimum chronological out-of-sample AUC: 0.733063 AUC
37	Effective dimensionality	Geometry and information	CMP-KRN, CMP-STA, CMP-LRN	REQ-F-003, REQ-F-006, REQ-F-013, REQ-Q-002	TST-LAB-037 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_37_effective_dimension.csv	PASS	Spearman anisotropy-dimension correlation: -1 correlation
38	Local Jacobian conditioning	Geometry and information	CMP-KRN, CMP-STA, CMP-LRN	REQ-F-003, REQ-F-006, REQ-F-013, REQ-Q-002	TST-LAB-038 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_38_jacobian_conditioning.csv	PASS	Boundary/interior condition ratio: 19.5472 multiple
39	S ³ geodesic-chord equivalence	Geometry and information	CMP-KRN, CMP-STA, CMP-LRN	REQ-F-003, REQ-F-006, REQ-F-013, REQ-Q-002	TST-LAB-039 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_39_s3_geodesic_chord.csv	PASS	Maximum identity error: 1.83187e-15 absolute error
40	Capacity level-set volume	Geometry and information	CMP-KRN, CMP-STA, CMP-LRN	REQ-F-003, REQ-F-006, REQ-F-013, REQ-Q-002	TST-LAB-040 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_40_capacity_level-set_volume.csv	PASS	Monotonicity violations: 0 count
41	Coordinate-contribution entropy	Geometry and information	CMP-KRN, CMP-STA, CMP-LRN	REQ-F-003, REQ-F-006, REQ-F-013, REQ-Q-002	TST-LAB-041 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_41_contribution_entropy.csv	PASS	Spearman HHI-entropy correlation: -0.998421 correlation
42	Base-fiber mutual information	Geometry and information	CMP-KRN, CMP-STA, CMP-LRN	REQ-F-003, REQ-F-006, REQ-F-013, REQ-Q-002	TST-LAB-042 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_42_base_fiber_mutual_information.csv	PASS	Empirical/analytic maximum error: 0.0168594 nats
43	Capacity-surface curvature	Geometry and information	CMP-KRN, CMP-STA, CMP-LRN	REQ-F-003, REQ-F-006, REQ-F-013, REQ-Q-002	TST-LAB-043 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_43_capacity_surface_curvature.csv	PASS	Maximum Hessian relative error: 1.27788e-07 fraction
44	Stress-cluster persistence	Geometry and information	CMP-KRN, CMP-STA, CMP-LRN	REQ-F-003, REQ-F-006, REQ-F-013, REQ-Q-002	TST-LAB-044 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_44_stress_cluster_persistence.csv	PASS	Two-cluster persistence span: 0.928571 fraction of thresholds
45	Lyapunov contraction	Dynamics and control	CMP-DYN, CMP-SIM, CMP-DEC	REQ-F-009, REQ-F-010, REQ-F-011	TST-LAB-045 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_45_lyapunov_contraction.csv	PASS	Estimated contraction exponent: -0.223192 log-distance per step

Rel.	Laboratory	Family	Components	Requirements	Test / controls	Evidence	Status	Baseline result
46	Critical slowing down	Dynamics and control	CMP-DYN, CMP-SIM, CMP-DEC	REQ-F-009, REQ-F-010, REQ-F-011	TST-LAB-046 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_46_critical_slowing.csv	PASS	Maximum recovery-time mismatch: 0 steps
47	Basin-of-attraction boundary	Dynamics and control	CMP-DYN, CMP-SIM, CMP-DEC	REQ-F-009, REQ-F-010, REQ-F-011	TST-LAB-047 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_47_basin_of_attraction.csv	PASS	Estimated basin boundary: 0 state units
48	Delay-induced oscillation	Dynamics and control	CMP-DYN, CMP-SIM, CMP-DEC	REQ-F-009, REQ-F-010, REQ-F-011	TST-LAB-048 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_48_delay_oscillation.csv	PASS	Peak delayed/no-delay oscillation ratio: 57.3042 multiple
49	Damping ratio and overshoot	Dynamics and control	CMP-DYN, CMP-SIM, CMP-DEC	REQ-F-009, REQ-F-010, REQ-F-011	TST-LAB-049 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_49_damping_overshoot.csv	PASS	Maximum overshoot error: 2.56553e-07 fraction
50	Minimum control-energy scaling	Dynamics and control	CMP-DYN, CMP-SIM, CMP-DEC	REQ-F-009, REQ-F-010, REQ-F-011	TST-LAB-050 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_50_control_energy.csv	PASS	Maximum analytic/constructed energy error: 5.55112e-17 energy
51	Resonance under periodic forcing	Dynamics and control	CMP-DYN, CMP-SIM, CMP-DEC	REQ-F-009, REQ-F-010, REQ-F-011	TST-LAB-051 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_51_resonance.csv	PASS	Peak-frequency error: 0.00121019 frequency units
52	Adaptive feedback stabilization	Dynamics and control	CMP-DYN, CMP-SIM, CMP-DEC	REQ-F-009, REQ-F-010, REQ-F-011	TST-LAB-052 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_52_adaptive_feedback.csv	PASS	RMS-state reduction: 0.998713 fraction
53	k-core depth and cascade reach	Network structure	CMP-GPH, CMP-RSK, CMP-SIM	REQ-F-007, REQ-F-008, REQ-F-010, REQ-F-015	TST-LAB-053 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_53_k-core_cascade.csv	PASS	Spearman core-cascade correlation: 0.922099 correlation
54	Community modularity and containment	Network structure	CMP-GPH, CMP-RSK, CMP-SIM	REQ-F-007, REQ-F-008, REQ-F-010, REQ-F-015	TST-LAB-054 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_54_modularity_containment.csv	PASS	Spearman modularity-containment correlation: 0.844845 correlation
55	Edge betweenness and contagion bridges	Network structure	CMP-GPH, CMP-RSK, CMP-SIM	REQ-F-007, REQ-F-008, REQ-F-010, REQ-F-015	TST-LAB-055 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_55_bridge_betweenness.csv	PASS	Connectivity reduction advantage: 0.25 fraction
56	Multiplex-layer coupling	Network structure	CMP-GPH, CMP-RSK, CMP-SIM	REQ-F-007, REQ-F-008, REQ-F-010, REQ-F-015	TST-LAB-056 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_56_multiplex_coupling.csv	PASS	Coupling-threshold Spearman correlation: -1 correlation
57	Assortativity and shock amplification	Network structure	CMP-GPH, CMP-RSK, CMP-SIM	REQ-F-007, REQ-F-008, REQ-F-010, REQ-F-015	TST-LAB-057 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_57_assortativity_amplification.csv	PASS	Assortativity-amplification correlation: 0.921193 correlation
58	Path redundancy and resilience	Network structure	CMP-GPH, CMP-RSK, CMP-SIM	REQ-F-007, REQ-F-008, REQ-F-010, REQ-F-015	TST-LAB-058 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_58_redundancy_resilience.csv	PASS	Maximum connectivity error: 0.00157714 fraction
59	Network percolation threshold	Network structure	CMP-GPH, CMP-RSK, CMP-SIM	REQ-F-007, REQ-F-008, REQ-F-010, REQ-F-015	TST-LAB-059 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_59_percolation_threshold.csv	PASS	Estimated-threshold error: 0.114286 mean-degree units
60	Targeted versus random node removal	Network structure	CMP-GPH, CMP-RSK, CMP-SIM	REQ-F-007, REQ-F-008, REQ-F-010, REQ-F-015	TST-LAB-060 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_60_targeted_removal.csv	PASS	Mean targeted-removal disadvantage: 0.926556 fraction
61	Fisher information and excitation	Learning and uncertainty	CMP-LRN, CMP-CFG, CMP-EVD	REQ-F-012, REQ-F-013, REQ-F-014, REQ-F-017, REQ-F-018	TST-LAB-061 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_61_fisher_information.csv	PASS	Maximum Hessian relative error: 1.0504e-06 fraction
62	Bias-variance tradeoff	Learning and uncertainty	CMP-LRN, CMP-CFG, CMP-EVD	REQ-F-012, REQ-F-013, REQ-F-014, REQ-F-017, REQ-F-018	TST-LAB-062 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_62_bias_variance.csv	PASS	High-degree/minimum MSE ratio: 408.648 multiple
63	Regularization path	Learning and uncertainty	CMP-LRN, CMP-CFG, CMP-EVD	REQ-F-012, REQ-F-013, REQ-F-014, REQ-F-017, REQ-F-018	TST-LAB-063 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_63_regularization_path.csv	PASS	Lambda-norm Spearman correlation: -1 correlation
64	Feature collinearity and coefficient instability	Learning and uncertainty	CMP-LRN, CMP-CFG, CMP-EVD	REQ-F-012, REQ-F-013, REQ-F-014, REQ-F-017, REQ-F-018	TST-LAB-064 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_64_collinearity.csv	PASS	Correlation-collinearity variance correlation: 0.948872 correlation
65	Sample complexity	Learning and uncertainty	CMP-LRN, CMP-CFG, CMP-EVD	REQ-F-012, REQ-F-013, REQ-F-014, REQ-F-017, REQ-F-018	TST-LAB-065 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_65_sample_complexity.csv	PASS	Log-log error slope: -0.620605 slope
66	Domain-shift sensitivity	Learning and uncertainty	CMP-LRN, CMP-CFG, CMP-EVD	REQ-F-012, REQ-F-013, REQ-F-014, REQ-F-017, REQ-F-018	TST-LAB-066 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_66_domain_shift.csv	PASS	Shift-error Spearman correlation: 0.997059 correlation
67	Conformal prediction coverage	Learning and uncertainty	CMP-LRN, CMP-CFG, CMP-EVD	REQ-F-012, REQ-F-013, REQ-F-014, REQ-F-017, REQ-F-018	TST-LAB-067 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_67_conformal_coverage.csv	PASS	Maximum absolute coverage error: 0.0135714 fraction
68	Ensemble diversity benefit	Learning and uncertainty	CMP-LRN, CMP-CFG, CMP-EVD	REQ-F-012, REQ-F-013, REQ-F-014, REQ-F-017, REQ-F-018	TST-LAB-068 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_68_ensemble_diversity.csv	PASS	Diversity-improvement correlation: 1 correlation
69	Expected shortfall versus capacity radius	Risk and allocation	CMP-RSK, CMP-DEC, CMP-SIM	REQ-F-015, REQ-F-017, REQ-F-024	TST-LAB-069 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relationship_69_expected_shortfall.csv	PASS	Radius-ES Spearman correlation: -1 correlation

Rel.	Laboratory	Family	Components	Requirements	Test / controls	Evidence	Status	Baseline result
70	Tail dependence beyond correlation	Risk and allocation	CMP-RSK, CMP-DEC, CMP-SIM	REQ-F-015, REQ-F-017, REQ-F-024	TST-LAB-070 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relation-ship_70_tail_dependence.csv	PASS	Student-t/Gaussian tail-dependence ratio: 1.82267 multiple
71	Diversification under correlation	Risk and allocation	CMP-RSK, CMP-DEC, CMP-SIM	REQ-F-015, REQ-F-017, REQ-F-024	TST-LAB-071 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relation-ship_71_diversification_correlation.csv	PASS	Maximum variance error: 0.00783185 variance units
72	Kelly sizing under uncertainty	Risk and allocation	CMP-RSK, CMP-DEC, CMP-SIM	REQ-F-015, REQ-F-017, REQ-F-024	TST-LAB-072 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relation-ship_72_kelly_uncertainty.csv	PASS	Mean shrinkage growth advantage: 0.00230862 log-growth per bet
73	Drawdown-duration dynamics	Risk and allocation	CMP-RSK, CMP-DEC, CMP-SIM	REQ-F-015, REQ-F-017, REQ-F-024	TST-LAB-073 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relation-ship_73_drawdown_duration.csv	PASS	Drift-duration Spearman correlation: -0.973422 correlation
74	Risk-budget attribution	Risk and allocation	CMP-RSK, CMP-DEC, CMP-SIM	REQ-F-015, REQ-F-017, REQ-F-024	TST-LAB-074 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relation-ship_74_risk_budget_attribution.csv	PASS	Maximum additivity error: 8.88178e-16 variance units
75	Transaction-cost break-even	Risk and allocation	CMP-RSK, CMP-DEC, CMP-SIM	REQ-F-015, REQ-F-017, REQ-F-024	TST-LAB-075 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relation-ship_75_transaction_cost_breakeven.csv	PASS	Grid break-even error: 1.7229e-05 cost units
76	Liquidity and square-root slippage	Risk and allocation	CMP-RSK, CMP-DEC, CMP-SIM	REQ-F-015, REQ-F-017, REQ-F-024	TST-LAB-076 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relation-ship_76_liquidity_slippage.csv	PASS	Estimated log-log slope error: 0.00216531 slope
77	Outlier influence and robust estimation	Robustness and data quality	CMP-ING, CMP-LRN, CMP-RSK	REQ-F-004, REQ-F-016, REQ-Q-003	TST-LAB-077 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relation-ship_77_outlier_influence.csv	PASS	OLS/Huber error ratio at 20% contamination: 12.9524 multiple
78	Heavy-tail robustness	Robustness and data quality	CMP-ING, CMP-LRN, CMP-RSK	REQ-F-004, REQ-F-016, REQ-Q-003	TST-LAB-078 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relation-ship_78_heavy_tail_robustness.csv	PASS	Mean/MoM RMSE ratio: 1.71291 multiple
79	Adversarial coordinate perturbation	Robustness and data quality	CMP-ING, CMP-LRN, CMP-RSK	REQ-F-004, REQ-F-016, REQ-Q-003	TST-LAB-079 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relation-ship_79_adversarial_perturbation.csv	PASS	Adversarial/positive-random mean damage ratio: 5.06971 multiple
80	Label-noise attenuation and ranking resilience	Robustness and data quality	CMP-ING, CMP-LRN, CMP-RSK	REQ-F-004, REQ-F-016, REQ-Q-003	TST-LAB-080 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relation-ship_80_label_noise.csv	PASS	Noise-coefficient-norm Spearman correlation: -1 correlation
81	Delayed-data degradation	Robustness and data quality	CMP-ING, CMP-LRN, CMP-RSK	REQ-F-004, REQ-F-016, REQ-Q-003	TST-LAB-081 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relation-ship_81_data_delay.csv	PASS	Delay-AUC Spearman correlation: -1 correlation
82	Asynchronous-sampling attenuation	Robustness and data quality	CMP-ING, CMP-LRN, CMP-RSK	REQ-F-004, REQ-F-016, REQ-Q-003	TST-LAB-082 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relation-ship_82_asynchronous_sampling.csv	PASS	Window-correlation Spearman correlation: 1 correlation
83	Coordinate quantization precision	Robustness and data quality	CMP-ING, CMP-LRN, CMP-RSK	REQ-F-004, REQ-F-016, REQ-Q-003	TST-LAB-083 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001	relation-ship_83_quantization.csv	PASS	Log2 RMSE slope per bit: -1.01066 slope
84	Model-version reproducibility	Causality and operations	CMP-LRN, CMP-OBS, CMP-EVD, CMP-GOV	REQ-F-012, REQ-F-014, REQ-F-018, REQ-F-020, REQ-G-006	TST-LAB-084 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001; CTRL-GOV-001	relation-ship_84_version_drift.csv	PASS	Drifted-version RMSE: 0.217591 prediction units
85	Directional Granger predictability	Causality and operations	CMP-LRN, CMP-OBS, CMP-EVD, CMP-GOV	REQ-F-012, REQ-F-014, REQ-F-018, REQ-F-020, REQ-G-006	TST-LAB-085 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001; CTRL-GOV-001	relation-ship_85_granger_direction.csv	PASS	Forward-direction p-value: 0 probability
86	Intervention-response recovery	Causality and operations	CMP-LRN, CMP-OBS, CMP-EVD, CMP-GOV	REQ-F-012, REQ-F-014, REQ-F-018, REQ-F-020, REQ-G-006	TST-LAB-086 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001; CTRL-GOV-001	relation-ship_86_intervention_response.csv	PASS	Maximum intervention-effect error: 0 outcome units
87	Counterfactual structural consistency	Causality and operations	CMP-LRN, CMP-OBS, CMP-EVD, CMP-GOV	REQ-F-012, REQ-F-014, REQ-F-018, REQ-F-020, REQ-G-006	TST-LAB-087 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001; CTRL-GOV-001	relation-ship_87_counterfactual_consistency.csv	PASS	Maximum counterfactual identity error: 1.33227e-15 outcome units
88	Confounding and adjustment	Causality and operations	CMP-LRN, CMP-OBS, CMP-EVD, CMP-GOV	REQ-F-012, REQ-F-014, REQ-F-018, REQ-F-020, REQ-G-006	TST-LAB-088 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001; CTRL-GOV-001	relation-ship_88_confounding_adjustment.csv	PASS	Error reduction at strongest confounding: 0.976798 fraction
89	Lead-lag estimation	Causality and operations	CMP-LRN, CMP-OBS, CMP-EVD, CMP-GOV	REQ-F-012, REQ-F-014, REQ-F-018, REQ-F-020, REQ-G-006	TST-LAB-089 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001; CTRL-GOV-001	relation-ship_89_lead_lag.csv	PASS	Exact-lag recovery rate: 1 fraction
90	Future-regime leakage in validation	Causality and operations	CMP-LRN, CMP-OBS, CMP-EVD, CMP-GOV	REQ-F-012, REQ-F-014, REQ-F-018, REQ-F-020, REQ-G-006	TST-LAB-090 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001; CTRL-GOV-001	relation-ship_90_seasonality_leakage.csv	PASS	Shuffled-validation optimism: 0.843946 AUC
91	Change-point detection	Causality and operations	CMP-LRN, CMP-OBS, CMP-EVD, CMP-GOV	REQ-F-012, REQ-F-014, REQ-F-018, REQ-F-020, REQ-G-006, REQ-G-006	TST-LAB-091 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001; CTRL-GOV-001	relation-ship_91_change-point_detection.csv	FAIL	Median detection delay: 9 steps

Rel.	Laboratory	Family	Components	Requirements	Test / controls	Evidence	Status	Baseline result
92	Forecast-horizon decay	Causality and operations	CMP-LRN, CMP-OBS, CMP-EVD, CMP-GOV	REQ-F-012, REQ-F-014, REQ-F-018, REQ-F-020, REQ-G-006	TEST-LAB-092 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001; CTRL-GOV-001	relationship_92_horizon_decay.csv	PASS	Maximum R ² -law error: 0.0049466 fraction
93	Decision-threshold stability	Deployment and governance	CMP-GOV, CMP-EVD, CMP-OPS, CMP-OBS, CMP-DEC	REQ-F-014, REQ-F-017, REQ-F-018, REQ-F-021, REQ-F-023, REQ-G-005	TST-LAB-093 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001; CTRL-GOV-001	relationship_93_threshold_stability.csv	PASS	Bootstrap threshold IQR: 0.0217877 probability
94	Benchmark-superiority gate	Deployment and governance	CMP-GOV, CMP-EVD, CMP-OPS, CMP-OBS, CMP-DEC	REQ-F-014, REQ-F-017, REQ-F-018, REQ-F-021, REQ-F-023, REQ-G-005	TST-LAB-094 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001; CTRL-GOV-001	relationship_94_benchmark_gate.csv	PASS	Holdout AUC gain: 0.119727 AUC
95	Cost-adjusted out-of-sample performance	Deployment and governance	CMP-GOV, CMP-EVD, CMP-OPS, CMP-OBS, CMP-DEC	REQ-F-014, REQ-F-017, REQ-F-018, REQ-F-021, REQ-F-023, REQ-G-005	TST-LAB-095 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001; CTRL-GOV-001	relationship_95_cost_adjusted_oos.csv	PASS	Net annualized Sharpe: 1.27651 Sharpe ratio
96	Integrated stress-scenario composition	Deployment and governance	CMP-GOV, CMP-EVD, CMP-OPS, CMP-OBS, CMP-DEC	REQ-F-014, REQ-F-017, REQ-F-018, REQ-F-021, REQ-F-023, REQ-G-005	TST-LAB-096 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001; CTRL-GOV-001	relationship_96_stress_scenarios.csv	PASS	Maximum scenario-composition error: 4.63185e-12 log-capacity units
97	Predictive-uncertainty decomposition	Deployment and governance	CMP-GOV, CMP-EVD, CMP-OPS, CMP-OBS, CMP-DEC	REQ-F-014, REQ-F-017, REQ-F-018, REQ-F-021, REQ-F-023, REQ-G-005	TST-LAB-097 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001; CTRL-GOV-001	relationship_97_uncertainty_decomposition.csv	PASS	Maximum Monte Carlo decomposition error: 0.0043404 variance units
98	Human-model decision fusion	Deployment and governance	CMP-GOV, CMP-EVD, CMP-OPS, CMP-OBS, CMP-DEC	REQ-F-014, REQ-F-017, REQ-F-018, REQ-F-021, REQ-F-023, REQ-G-005	TST-LAB-098 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001; CTRL-GOV-001	relationship_98_human_model_fusion.csv	PASS	Fusion AUC gain over best component: 0.028204 AUC
99	Cross-seed reproducibility	Deployment and governance	CMP-GOV, CMP-EVD, CMP-OPS, CMP-OBS, CMP-DEC	REQ-F-014, REQ-F-017, REQ-F-018, REQ-F-021, REQ-F-023, REQ-G-005	TST-LAB-099 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001; CTRL-GOV-001	relationship_99_seed_reproducibility.csv	PASS	Across-seed coefficient of variation: 0.00499983 fraction
100	Integrated 8Sphere validation gate	Deployment and governance	CMP-GOV, CMP-EVD, CMP-OPS, CMP-OBS, CMP-DEC	REQ-F-014, REQ-F-017, REQ-F-018, REQ-F-021, REQ-F-023, REQ-G-005	TST-LAB-100 / CTRL-EVD-001; CTRL-CHG-001; CTRL-VAL-001; CTRL-GOV-001	relationship_100_integrated_validation_gate.csv	PASS	Integrated evidence score: 0.952191 score from 0 to 1

4. Requirement Coverage

Requirement	Summary	Laboratory / verification basis
REQ-F-001	Represent every state as five bounded coordinates and one normalized S3 fiber.	1, 2, 3, 4, 5, 6, 7
REQ-F-002	Compute hard, softened, and weighted capacity radii with versioned parameters.	1, 2, 3, 4, 5, 6, 7, 13, 14, 15, 16, 17, 18, 19
REQ-F-003	Compute damage contributions, gradients, elasticities, Hessians, curvature, and conditioning.	1, 2, 3, 4, 5, 6, 7, 13, 14, 15, 16, 17, 18, 19, 37, 38, 39, 40, 41, 42, 43, 44
REQ-F-004	Validate bounds, norm, units, timestamps, missingness, and numerical finiteness before use.	1, 2, 3, 4, 5, 6, 7, 25, 26, 27, 28, 29, 30, 31, 77, 78, 79, 80, 81, 82, 83
REQ-F-005	Distinguish observed, derived, estimated, simulated, and human-entered values.	Design, security, operations, or human verification
REQ-F-006	Compute S3 geodesic, chord, orientation change, and path-dependent transport diagnostics.	13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 37, 38, 39, 40, 41, 42, 43, 44
REQ-F-007	Represent signed, directed, weighted, delayed, and multiplex relationships.	8, 9, 10, 11, 12, 53, 54, 55, 56, 57, 58, 59, 60
REQ-F-008	Compute spectral, centrality, influence, community, core, bridge, redundancy, and percolation measures.	20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 53, 54, 55, 56, 57, 58, 59, 60
REQ-F-009	Simulate propagation, synchronization, activation, recovery, hysteresis, delay, resonance, and feedback.	8, 9, 10, 11, 12, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 45, 46, 47, 48, 49, 50, 51, 52
REQ-F-010	Run isolated targeted and random scenarios with explicit resource and parameter limits.	45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60
REQ-F-011	Estimate intervention energy, expected benefit, uncertainty, side effects, and reversibility.	45, 46, 47, 48, 49, 50, 51, 52
REQ-F-012	Use chronological partitions by default for time-dependent model validation.	32, 33, 34, 35, 36, 61, 62, 63, 64, 65, 66, 67, 68, 84, 85, 86, 87, 88, 89, 90, 91, 92
REQ-F-013	Measure calibration, conformal coverage, shift, bias-variance, collinearity, sample sufficiency, and leakage.	32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 61, 62, 63, 64, 65, 66, 67, 68
REQ-F-014	Compare models against frozen benchmarks and versioned thresholds.	32, 33, 34, 35, 36, 61, 62, 63, 64, 65, 66, 67, 68, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100
REQ-F-015	Compute expected shortfall, tail dependence, diversification, risk budget, drawdown, cost, and liquidity.	8, 9, 10, 11, 12, 53, 54, 55, 56, 57, 58, 59, 60, 69, 70, 71, 72, 73, 74, 75, 76
REQ-F-016	Quantify sensitivity to missingness, delay, asynchronous data, noise, outliers, heavy tails, adversarial perturbation, and quantization.	25, 26, 27, 28, 29, 30, 31, 77, 78, 79, 80, 81, 82, 83
REQ-F-017	Decompose predictive uncertainty and preserve human and model contributions in fused decisions.	61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 93, 94, 95, 96, 97, 98, 99, 100
REQ-F-018	Generate immutable evidence for every material computation, simulation, model, alert, decision, and release.	8, 9, 10, 11, 12, 20, 21, 22, 23, 24, 32, 33, 34, 35, 36, 61, 62, 63, 64, 65, 66, 67, 68, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100
REQ-F-019	Evidence shall include inputs, hashes, code, configuration, parameters, seed, environment, outputs, tests, and approvals.	Design, security, operations, or human verification
REQ-F-020	The Observatory shall expose state, history, claim class, uncertainty, network exposure, model health, alerts, and evidence.	84, 85, 86, 87, 88, 89, 90, 91, 92
REQ-F-021	Support acknowledgment, investigation, escalation, approval, rejection, dispatch, rollback, and closure workflows.	93, 94, 95, 96, 97, 98, 99, 100

Requirement	Summary	Laboratory / verification basis
REQ-F-022	Support single-node, air-gapped, private-network, and high-availability deployment profiles.	Design, security, operations, or human verification
REQ-F-023	Provide backup, restore, update, rollback, disaster recovery, and integrity verification.	93, 94, 95, 96, 97, 98, 99, 100
REQ-F-024	Prevent advisory outputs from becoming autonomous actions without explicit policy and authority.	69, 70, 71, 72, 73, 74, 75, 76
REQ-Q-001	Deterministic functions shall reproduce byte-stable or tolerance-equivalent outputs from identical signed inputs.	Design, security, operations, or human verification
REQ-Q-002	Numerical functions shall meet laboratory tolerances and report conditioning or precision warnings.	1, 2, 3, 4, 5, 6, 7, 13, 14, 15, 16, 17, 18, 19, 37, 38, 39, 40, 41, 42, 43, 44
REQ-Q-003	Material outputs shall be explainable and traceable to immutable evidence.	77, 78, 79, 80, 81, 82, 83
REQ-Q-004	Core operation shall not require a public internet connection.	Design, security, operations, or human verification
REQ-Q-005	Graph, simulation, batch, and interactive workloads shall be independently governable and scalable.	Design, security, operations, or human verification
REQ-Q-006	The interface and reports shall support keyboard access, meaningful labels, contrast, scalable text, and non-color status cues.	Design, security, operations, or human verification
REQ-S-001	Authenticate every user and service before non-public access.	Design, security, operations, or human verification
REQ-S-002	Enforce least privilege, separation of duties, and environment-specific authorization.	Design, security, operations, or human verification
REQ-S-003	Require recorded approval for privileged changes to models, thresholds, policy, identity, and releases.	Design, security, operations, or human verification
REQ-S-004	Protect sensitive data and evidence in transit and at rest.	Design, security, operations, or human verification
REQ-S-005	Hash and, where supported, sign releases, evidence, configuration, and offline updates.	Design, security, operations, or human verification
REQ-S-006	Sandbox and validate untrusted files, data, models, and removable-media packages.	Design, security, operations, or human verification
REQ-S-007	Record protected security and privileged-operation audit events.	Design, security, operations, or human verification
REQ-S-008	Support incident containment, credential revocation, evidence preservation, recovery, and review.	Design, security, operations, or human verification
REQ-G-001	Assign every output a claim class: mathematical, synthetic, empirical, predictive, advisory, or automated action.	32, 33, 34, 35, 36
REQ-G-002	SOPHIA shall prevent unsupported promotion of synthetic results to empirical claims.	Design, security, operations, or human verification
REQ-G-003	CHARLOTTE shall validate terminology, units, schemas, traceability, and evidence completeness.	Design, security, operations, or human verification
REQ-G-004	LANDON shall execute approved workflows and attach reproducible execution evidence.	Design, security, operations, or human verification
REQ-G-005	Material releases and actions require independent validation and accountable human approval.	93, 94, 95, 96, 97, 98, 99, 100
REQ-G-006	Known failures and limitations shall remain visible, including Relationship 91 and Relationship 12 evidence limits.	84, 85, 86, 87, 88, 89, 90, 91, 92

5. Gap Register

Gap	Required evidence
Domain semantics	approved coordinate, fiber, graph, target, cost, and decision definitions
External validity	chronological real-data study and independent replication
Relationship 91	new protocol meeting delay and false-alarm gates
Relationship 12	recover run-level evidence or reproduce under a new protocol
Security	threat-control evidence for the selected deployment
Human factors	comprehension, alert load, override, and decision-fusion study
Operations	installation, failover, backup, restore, update, rollback, incident rehearsal
Action safety	bounded pilot, kill switch, receipt reconciliation, accountable risk acceptance

6. Package Readiness Summary

Gate area	Baseline state	Release implication
Mathematical conformance	Relationships 1-44 provide the deterministic geometry, conditioning, information, and state foundations.	Maintain the frozen formulas, tolerances, and numerical warnings as permanent regressions.
Network and dynamic behavior	Relationships 45-60 establish the controlled simulation baseline for stability, propagation, cascades, topology, and intervention.	Production use requires domain-specific graph semantics, resource limits, and independent scenario review.
Learning, calibration, and risk	Relationships 61-83 provide the synthetic baseline for estimation, uncertainty, calibration, tails, costs, and robustness.	No predictive or financial claim may be promoted without chronological real-data validation and benchmark comparison.
Operational and governance controls	Relationships 84-100 support monitoring, causal checks, deployment controls, and evidence gates.	Relationship 91 remains an open failed gate; its false-alarm criterion must be satisfied under a new frozen protocol.
Security and operations	Threat controls, signed releases, backup, restore, rollback, and incident procedures are specified.	The selected deployment must produce threat-control evidence, recovery evidence, and accountable security approval.
External production readiness	Domain semantics, human factors, external validity, and bounded-pilot evidence remain outstanding.	The design package is an engineering baseline, not a production authorization.

Final authorization sequence. SOPHIA confirms the permitted claim and action class; CHARLOTTE confirms architectural, terminology, unit, schema, and traceability conformance; LANDON reproduces the approved workflow and evidence; independent validation and security authorities review the result; the accountable system owner accepts or rejects residual risk and deployment.

END OF CONTROLLED DOCUMENT 10