

# Physical Bridge Claim Registry for Active Finite Distinction Systems: Time, Observers, Horizons, Topological Persistence, and High-Risk Physical Extensions

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This paper registers the principal physical bridge claims of Distinction Theory, a finite-system framework in which identity maintenance under finite capacity generates approximation, corrective complexity, dissipative pressure, pruning, collapse, or invariant-supported persistence. Unlike the FDS Core, which defines the formal finite-system architecture, and a forthcoming companion AI paper, which applies it to artificial agency, the present work organizes physical extensions by dependency, tier, falsification condition, and empirical status. The registry does not claim to derive the Standard Model, fix coupling constants, solve quantum gravity, or replace established physical theories. Instead, it identifies a set of bridge claims connecting finite distinguishability, observer-relative boundaries, irreversible distinction updates, horizon thermodynamics, topological persistence, CP/T-asymmetric identity transformation, and several quarantined high-risk interpretive extensions concerning particle identity and interaction functions. Each claim is assigned a scope, risk level, prior-art relation, and death condition. The purpose is priority, auditability, and future model development, not immediate consensus.

## EPISTEMIC STATUS

This document is a claim registry, not a completed physical theory. It records physical bridge claims derived from, adjacent to, or motivated by the FDS formal core. Formal results remain in the FDS Core. Physical claims require additional bridge assumptions and may fail independently.

The registry has three purposes: (i) priority and timestamping, (ii) dependency and risk classification, (iii) preparation for future standalone physical papers.

A claim listed here is not thereby asserted as established physics. Each claim is assigned a tier, dependencies, prior-art relation, novelty statement, falsification condition, empirical status, and required next work.

## VERSIONING

This is Public Registry v1.0. Claims may be promoted, demoted, split, merged, or retired in later versions. A version change does not imply that the entire FDS programme has changed; it records the current status of physical bridge claims only.

## INTRODUCTION: WHY A PHYSICAL REGISTRY IS NEEDED

### From finite-system architecture to physical bridge claims

The core architecture of Distinction Theory begins from the finite-system cost chain:

Distinction  $\rightarrow$  boundary  $\rightarrow$  capacity deficit  $\rightarrow$  approximation  
 $\rightarrow$  corrective complexity  $\rightarrow$  dissipative pressure  
 $\rightarrow$  pruning / collapse / invariant-supported persistence.

The present paper does not re-derive that core chain. It asks a different question: if finite systems are physically instantiated, what kinds of physical structures should one expect to appear? The answer is not a single finished theory of physics. It is a registry of bridge claims connecting the finite-system architecture to physical notions such as observerhood, time, causal speed, horizon entropy, gravity, dark energy, topological protection, CP/T asymmetry, and the functional roles of the observed interactions.

The registry format is deliberate. Several of the claims below are close to existing physical traditions: Landauer erasure, Bekenstein bounds, horizon thermodynamics, emergent gravity, non-Hermitian topology, and CKM phase counting. Other claims are more speculative and should be treated as high-risk conjectures. The value of a registry is that it separates these cases. It prevents an interpretive bridge from being confused with a theorem, and it prevents the failure of one physical module from being misread as the failure of the finite-system architecture as a whole.

### Registry, not final theory

This paper is not a final physical theory. It does not derive the Standard Model gauge group, particle masses, coupling constants, the numerical value of  $G$ , the numerical value of  $c$ , or the full Einstein field equations from the distinction primitive alone. It also does not assert that every existing physical principle is merely an instance of

Distinction Theory. Its goal is narrower and more auditable: to state physical bridge claims, list their dependencies, identify prior-art neighbors, and specify what would falsify or demote each claim.

A useful comparison is with a map of possible research liabilities. A mature physical theory normally has equations, fit parameters, experiments, and community-vetted limits. A research programme begins earlier: it identifies candidate dependencies and where they can fail. The present registry is written in that earlier sense. It is intended to make the physical claim-space searchable, citable, and falsifiable.

#### Relation to the core finite-system paper

The FDS Core introduces the formal finite-system architecture. A forthcoming companion AI paper applies that architecture to artificial agency. The present registry takes up physical bridge modules excluded from the formal core and organizes them by dependency, tier, and falsification condition.

#### What is not claimed

Tier labels do not measure importance. They measure epistemic status. A Tier C claim may be more exciting than a Tier B claim, but it is less secure. A Tier D claim may be useful for interpretation while remaining nonessential to the finite-system architecture.

#### Failure propagation rule

The registry follows a downstream failure rule:

If a physical bridge claim fails, only that claim and its downstream modules are revised, demoted, quarantined, or abandoned. Failure of a physical bridge does not by itself falsify the distinction primitive or the bridge-free finite-system architecture.

This rule is crucial. Without it, the registry would become a brittle grand theory in which any failed physical speculation destroys the entire programme. The purpose of the registry is the opposite: to make each claim independently auditable.

#### Registry template

Each major claim is stated using the following template:

1. **Claim ID and name.**

2. **Tier.**

3. **Statement.**

4. **Dependencies.**

5. **Prior-art relation.**

6. **Novel DT contribution.**

7. **Falsification condition.**

8. **Empirical status.**

9. **Required next work.**

The template is intentionally repetitive. It makes visible the difference between a claim that is being asserted, a claim that is being interpreted, and a claim that is being proposed for future testing.

#### Claim-ID convention

The registry uses an explicit prefix system to avoid ambiguity. Each claim ID has the form  $XX-N$  where  $XX$  is a two-letter prefix identifying the claim family:

#### Risk stratification at a glance

The following table summarizes the relative strength of each claim family.

#### MINIMAL PHYSICAL BRIDGE ASSUMPTIONS

##### Finite distinguishability

**Assumption** (Finite distinguishability). A physically instantiated system that maintains identity has a finite distinguishability budget. Its internal record, memory, or state-maintenance capacity is bounded by finite physical resources.

This assumption is compatible with a broad range of existing ideas: finite entropy bounds, Bekenstein-type limits on information in bounded regions, finite memory in computation, and finite channel capacities in communication theory [3, 9, 11]. Distinction Theory does not require the strongest possible version of these bounds for every system. It requires only that physical systems maintaining identity do not possess infinite usable distinguishability.

Not claimed	Reason
FDS derives the Standard Model gauge group	Only functional bridge hypotheses registered; no derivation of $SU(3)_c \times SU(2)_L \times U(1)_Y$
FDS fixes coupling constants	No quantitative model yet; only structural roles registered
FDS derives $c$ numerically	Only finite causal access bridge proposed; no derivation of numerical value
FDS derives Einstein field equations	Only horizon-thermodynamic interpretation registered; no field-equation derivation
FDS solves quantum measurement	Observer is finite distinction-register, not collapse solution; interpretive only
FDS replaces QFT, GR, or SM	Registry is bridge map, not replacement theory
FDS proves dark energy	Only high-risk horizon-maintenance hypothesis; no derivation of $\Lambda$

Prefix Claim family

PB	Physical bridge assumptions (finite distinguishability, Landauer, finite causal access)
OT	Observer / Time claims (finite distinction-register, operational time, causal speed)
BC	Bounded computation claims (finite-memory reversible computation, dissipation)
HT	Horizon / Thermodynamic claims (horizon as distinguishability, gravity)
DE	Dark-energy claims (horizon-maintenance dark energy, $w(z)$ , area suppression)
TP	Topological persistence claims (invariant support, two-kink signature)
FG	Fermion generation claims (CKM lower bound, exact-three minimality)
FF	Fundamental force claims (functional decomposition)
PX	Pauli-exclusion claims (finite address protection)
SY	Symmetry claims (physical symmetries as low-maintenance invariants)
ME	Mass-energy claims (stored distinction, update capacity)
ST	Stochasticity claims (finite truncation, effective randomness)
QD	Decoherence claims (distinguishability leakage)
QC	Quantum computation claims (maintenance-cost barrier)
ML	Mathematical form claims (invariant compression)
QG	Quantum gravity / black-hole horizon claims (finite-distinguishability access boundary)
BH	Black-hole information claims (boundary encoding, finite observer recoverability)
PI	Particle identity claims (species as invariant-supported identity classes)
MS	Mass-spectrum claims (mass as identity-maintenance cost)
YK	Yukawa coupling claims (identity-transformation channel weights)
DM	Dark-matter claims (low-addressability gravitational distinction residue)
QM	Quantum measurement claims (measurement as finite record stabilization)
BR	Born-rule bridge (protective note: not derived)
YM	Yang–Mills confinement claims (boundary encapsulation of color distinctions)
MG	Mass-gap claims (minimum cost of stable distinction excitation)
GT	Gauge-redundancy claims (quotient over description-equivalent distinctions)
CI	Cosmological initial-condition claims (low-entropy initial macroscopic complexity)
IN	Inflation claims (horizon-scale distinction dilution)
CMB	Cosmic-microwave-background claims (Phase-B cosmological residue)
CA	Cosmological-arrow claims (record asymmetry under finite observers)
FR	Freeze-out claims (distinction stabilization across cooling expansion)

### Landauer bridge

**Assumption** (Landauer bridge). When a physically instantiated system performs a logically irreversible operation—erasure, many-to-one overwrite, reset, or compression of previously distinguishable states—there is a thermodynamic entropy cost under specified physical conditions.

The bridge is deliberately stated in a conservative form. Distinction Theory does not claim that every computation dissipates  $k_B T \ln 2$  per operation. Reversible computation, unitary evolution, read-only operations, and stable storage are not automatically charged with

this cost. The claim is that irreversible distinction loss, when physically implemented under appropriate thermal conditions, must be paid for in the total entropy budget [4–6].

### Locality and finite causal access

**Assumption** (Finite causal access). A finite physical system cannot instantaneously access, register, update, and causally use arbitrary distant distinctions without unbounded update capacity.

This assumption prepares the observer, time, and hori-

Module	Strength	Reason
Bounded-memory reversible computation	Strongest	Clear prior art (Landauer, Bennett); measurable garbage/reset/dissipation
Landauer bridge	Strong	Established physical basis; conservative use
Topological two-kink (TP-3)	Strong but novel	DT-specific observable; requires experimental proxy
Observer/Time (OT-1, OT-2)	Medium	Conceptual but structurally disciplined; clear falsifiers
Horizon/Gravity (HT-1, HT-2)	Medium	Strong prior art but no equations yet; needs concrete model
Dark energy (DE-1, DE-2, DE-3)	High-risk	High model-selection risk; needs specific $w(z)$ predictions
Fermion exact-three (FG-3)	High-risk	Needs rigorous link to flavor sector; speculative
Four forces (FF-1, FF-2)	Very high-risk	Currently functional mapping only; no quantitative model
Pauli address protection (PX-1)	Interpretive	Must not replace spin-statistics theorem; remains non-essential
BH/QG (BH-1, BH-2, QG-1)	Medium	Structurally disciplined but requires microscopic model
Dark matter (DM-1, DM-2)	High-risk	Needs concrete candidate identification or geometric model
QM/Records (QM-1, QM-2, QM-3)	Medium	Structurally grounded but Born rule remains prospective
Cosmology (CI-1, CMB-1, CA-1)	Medium	Broadly consistent but not DT-specific; requires concrete models
Confinement/Mass gap (YM-1, MG-1)	Very high-risk	Currently interpretive; needs quantitative FDS cost model
Particle identity (PI-1, MS-1, YK-1)	Very high-risk	Interpretive bridge to SM; no parameter derivation

zon claims. It is not a derivation of relativity. It is the finite-system precondition from which a maximum causal update rate becomes natural.

directly tested as a single experiment but constrains later claims about time, measurement, causal access, and horizon boundaries.

## OBSERVER AND TIME CLAIMS

### Claim OT-1: Observer as finite distinction-register

**Tier.** B.

**Statement.** An observer is not defined by consciousness, biological status, or human subjectivity. An observer is a finite distinction-register: a physical system capable of registering, preserving, updating, and ordering distinctions under finite capacity.

**Dependencies.** Finite distinguishability; boundary maintenance; record stability.

**Prior-art relation.** This claim touches the operational tradition in physics, the role of measurement records in quantum mechanics, and cybernetic accounts of observation. It does not depend on anthropocentric consciousness.

**Novel DT contribution.** Observerhood is redefined as a finite-system maintenance role. The observer is not an epistemic add-on to physics; it is the finite carrier of registered distinctions.

**Falsification condition.** A complete physical account of registered states that requires no finite distinction carrier, no record stability, no boundary, and no capacity constraint would undermine this claim.

**Empirical status.** Conceptual bridge claim. It is not

### Claim OT-2: Time as ordered irreversible distinction-update

**Tier.** B/B+.

**Statement.** Operational time is the ordered structure of irreversible distinction updates within finite systems. A finite record obtains temporal order because distinctions are registered, truncated, overwritten, or stabilized in a sequence that cannot be freely inverted without restoring erased degrees of freedom.

**Important limitation.** This claim does not deny mathematical recurrence in ideal finite-dimensional closed unitary systems. It denies that a physically erased or truncated distinction can reappear as an accessible physical record without external information restoration or entropy compensation.

**Dependencies.** Finite distinction-register; Landauer bridge; record stability; irreversible update.

**Prior-art relation.** The claim is adjacent to thermodynamic arrows of time, Landauer erasure, decoherence, and records-based accounts of temporal asymmetry [4, 5, 33–35]. It differs by locating the operational arrow in finite distinction registration rather than only in statistical entropy increase.

**Novel DT contribution.** The arrow is framed as a cost of finite record update: time is not only what clocks

measure, but what finite systems produce when they irreversibly update accessible distinctions.

**Falsification condition.** A demonstrated physical process that restores an actually erased distinction as an accessible record with complete accounting of reservoirs, correlations, feedback records, and work sources below the generalized Landauer bound would falsify the Landauer-dependent version of this claim.

**Claim OT-3: Finite and invariant causal speed from finite distinction access**

**Tier.** C/B.

**Statement.** A finite observer cannot instantaneously access, register, and causally use arbitrary distant distinctions without infinite update capacity. Therefore a finite physical world requires a maximum causal update rate. The invariance of this rate across admissible observers follows from the requirement of mutually consistent causal distinction orderings. When realized, this invariant rate plays the structural role of the speed  $c$ .

**Dependencies.** Finite causal access; observer as finite distinction-register; consistent record ordering.

**Prior-art relation.** Special relativity postulates an invariant causal speed and builds Lorentz kinematics around it [32]. Distinction Theory does not replace that derivation. It proposes an upstream finite-system reason why an invariant causal bound is necessary.

**Not claimed.** This registry does not derive the numerical value of  $c$  or Maxwell's equations.

**Falsification condition.** A finite observer capable of receiving, registering, and operationally using arbitrary instantaneous signals without record inconsistency, unbounded update capacity, or causal contradiction would undermine this bridge.

**Discussion.** The invariance of the causal bound follows from the requirement that mutually consistent causal distinction orderings be maintained across admissible observers. Operational infinite causal access with consistent records across all observers without resource bounds would falsify this consistency requirement.

**BOUNDED MEMORY, REVERSIBLE COMPUTATION, AND DISSIPATION**

**Claim BC-1: Finite open-ended reversible computation must eventually dissipate under bounded memory**

**Tier.** B+.

**Statement.** Reversible gates can avoid Landauer cost locally. However, a finite open-ended physical computer with bounded memory, persistent input/output, error

correction, state reuse, or garbage disposal must eventually perform irreversible compression, reset, or pruning, and therefore incur nonzero total dissipation.

**Dependencies.** Landauer bridge; finite memory; open-ended input/output; state reuse.

**Prior-art relation.** Reversible computation is a classical route to minimizing dissipation [6, 7]. The Distinction Theory claim is not that reversible gates are impossible. It is that finite open-ended operation cannot indefinitely avoid garbage accumulation or irreversible housekeeping.

**Novel DT contribution.** The claim links reversible computation to active pruning: finite systems avoid collapse not merely by computing reversibly, but by managing accumulated structural residue under bounded memory.

**Falsification condition.** A bounded-memory, open-ended physical computer that indefinitely performs nontrivial adaptive computation with persistent input/output and no irreversible reset, compression, error correction, garbage disposal, or entropy export would falsify the claim.

**Near-term test.** Construct finite-memory reversible circuits or computational substrates under continuous task streams. Measure garbage accumulation, reset frequency, error-correction overhead, and heat output as a function of task depth and memory budget.

**HORIZON, ENTROPY, AND GRAVITY**

**Prior-art boundary**

The gravity-related claims below must be read against a large body of prior work. Bekenstein and Hawking connected horizon area with entropy and temperature [8, 10]. Unruh related acceleration and temperature [12]. Jacobson derived the Einstein equation as an equation of state from horizon entropy and the Clausius relation  $\delta Q = TdS$  [13]. Induced and emergent gravity programmes have explored gravity as an effective or thermodynamic phenomenon [14–16]. Distinction Theory does not claim priority over these ideas. Its contribution is to interpret horizon thermodynamics as finite distinction maintenance under bounded observer capacity.

**Claim HT-1: Horizon as observer-relative distinguishability boundary**

**Tier.** B.

**Statement.** A horizon is the boundary of causal distinguishability for a finite observer-system. It is not merely a geometric surface; it is the boundary beyond which distinctions cannot be registered, updated, or operationally used by the observer within the relevant causal structure.

**Dependencies.** Finite causal access; finite distinction-register; causal boundary.

**Prior-art relation.** The claim is consistent with causal horizons, Rindler horizons, black-hole horizons, and holographic entropy bounds [9, 11, 13].

**Novel DT contribution.** The horizon is interpreted as an operational distinguishability boundary. Its thermodynamic properties reflect the cost of maintaining a finite causal-access boundary.

**Falsification condition.** A physically meaningful horizon with no relation to causal access, information bounds, record accessibility, or distinguishability constraints would undermine this claim.

### Claim HT-2: Gravity as effective geometry of horizon maintenance

**Tier.** C/B.

**Statement.** Gravity is the macroscopic equilibrium geometry of finite causal-access maintenance. Energy and information distributions constrain what can be distinguished, accessed, and updated; in the equilibrium continuum limit, this constraint appears as effective geometry.

**Dependencies.** Horizon as distinguishability boundary; finite entropy; thermodynamic horizon relation.

**Prior-art relation.** This claim is adjacent to Jacobson's thermodynamic derivation, Sakharov induced gravity, entropic gravity, and analogue gravity [13–15, 17].

**Not claimed.** This paper does not derive the full Einstein field equations, the value of Newton's constant, or a microscopic quantum gravity model.

**Falsification condition.** A complete physical account of gravitational geometry in which horizons, entropy, finite causal access, and distinguishability constraints play no necessary role would demote this claim to a nonessential analogy.

### Claim HT-3: Non-equilibrium gravitational corrections

**Tier.** B+/C.

**Statement.** If Einstein geometry is the equilibrium limit of horizon maintenance, then far-from-equilibrium horizon regimes should admit corrections controlled by distinguishability saturation, maintenance delay, or horizon-mode registration.

**Candidate observables.** Analogue-horizon entropy-production kinks, black-hole ringdown corrections, modified gravitational-wave propagation, or early-universe tensor-spectrum deviations.

**Risk note.** Astrophysical black-hole corrections may be extremely small, potentially scaling like  $1/S_{\text{BH}}$ . Analogue systems may provide more realistic tests.

**Falsification condition.** A confirmed horizon system driven far from equilibrium that shows no maintenance-cost anomaly, no entropy-production anomaly, and no distinguishability-saturation effect across a controlled regime would weaken this bridge.

### DARK ENERGY AS HORIZON MAINTENANCE COST

#### Claim DE-1: Horizon-scale dark-energy naturalness

**Tier.** C/B+.

**Statement.** If the cosmological horizon is a finite distinguishability boundary, its maintenance cost naturally scales as

$$\rho_{\text{DE}} \sim H^2 M_{\text{Pl}}^2. \quad (1)$$

**Dependencies.** Horizon as distinguishability boundary; finite entropy; cosmic causal boundary; physical bridge from maintenance cost to energy density.

**Prior-art relation.** The scaling resembles holographic dark energy and horizon-scale effective field theory arguments [19, 20]. Distinction Theory must be distinguished from standard HDE/RDE cutoff models, some of which are strongly constrained by current data.

**Novel DT contribution.** The scale is interpreted as horizon-maintenance cost of observer-relative distinguishability, not merely as an infrared cutoff imposed on quantum fields.

#### Claim DE-2: $10^{-122}$ as area-suppressed horizon ratio

**Tier.** C.

**Statement.** The observed dark-energy scale may be understood as an area-like horizon suppression:

$$\frac{\rho_{\text{DE}}}{\rho_{\text{Pl}}} \sim H_0^2 t_P^2 \sim \left(\frac{\ell_P}{R_H}\right)^2 \sim 10^{-122}. \quad (2)$$

**Interpretation.** A three-dimensional volume suppression would give a much smaller number. The DT interpretation is that horizon maintenance is boundary-like, not volume-like.

**Limitation.** This is a scaling/naturalness argument until embedded in a concrete cosmological evolution model.

#### Claim DE-3: Equation-of-state prediction

**Tier.** B+ / high-risk.

**Statement.** A strict horizon-maintenance model predicts dynamical dark energy with  $w(z) > -1$  and asymptotic approach toward  $-1$ , unless apparent phantom

crossing is produced by effective reconstruction, sector mixing, or parameterization artifacts.

**Empirical status.** DESI DR2 and combinations with CMB and supernova datasets have reported preferences for dynamical dark-energy parameterizations in some combinations, with model and dataset dependence [21, 22]. These data do not yet select the DT mechanism.

**Falsification condition.** Future DESI, Euclid, Roman, or CMB-S4 results that lock  $w(z) = -1$  to high precision would demote DE-3. Robust, unavoidable  $w < -1$  crossing incompatible with any DT effective reconstruction would falsify the strict inequality version.

**Required next work.** A concrete  $H(z)$  and  $w(z)$  model distinguishing DT horizon maintenance from standard holographic, Ricci, quintessence, phantom, and modified-gravity alternatives.

## TOPOLOGICAL PERSISTENCE AND THE SECOND-LAW BOUNDARY

### Prior-art boundary

Non-Hermitian topology has established that spectra, point gaps, boundary conditions, and skin accumulation can be tied to winding and non-Bloch topological structures [23–26]. Recent experiments have realized non-Hermitian skin effects in multiple platforms, including photonic, acoustic, electrical, and ultracold-atom systems [27]. Distinction Theory does not claim that NHSE itself is new. Its claim is that topological persistence can impose operational limits on local forgetting or coarse-graining.

### Claim TP-1: Invariant-supported persistence

**Tier.** B.

**Statement.** Under repeated pruning, local noise, or collapse, structures whose identity is carried by global invariants are lower-maintenance persistence carriers than structures requiring full local reconstruction.

**Dependencies.** Finite-system trichotomy; invariant-supported identity; local noise or perturbation.

**Prior-art relation.** The claim is consistent with symmetry protection, topological phases, conserved quantities, and error-protecting global invariants.

**Novel DT contribution.** Persistence is interpreted as a maintenance-cost problem: invariants survive because they reduce the burden of local repair.

### Claim TP-2: Topological obstruction to local forgetting

**Tier.** B+.

**Statement.** Local coarse-graining, forgetting, or dissipation may fail to erase globally protected topological invariants. The second law governs entropy accounting, but local forgetting may face invariant-supported boundary conditions.

**Important non-claim.** DT does not claim violation of the second law. It proposes a boundary on local forgetting and coarse-graining, not an exception to thermodynamics.

**Falsification condition.** A controlled topological system whose globally protected invariant can be erased by purely local Markovian forgetting with no nonlocal operation, phase transition, or compensating entropy channel would weaken this claim.

### Claim TP-3: Two-kink experimental signature

Flagship near-term experimental protocol. TP-3 is the registry’s most concrete DT-specific experimental proposal: it predicts paired non-analytic behavior in steady-state entropy production and operational forgetting rate at the same confirmed topological transition.

**Tier.** B+.

**Statement.** At a topological transition parameter  $\gamma_c$ , DT predicts paired non-analytic behavior in steady-state entropy production and operational forgetting rate:

$$\dot{\Sigma}_{\text{ss}}(\gamma) \quad \text{and} \quad \kappa(\gamma) \quad (3)$$

should exhibit aligned kinks at the same  $\gamma_c$ .

**Why this matters.** NHSE existence alone is not DT-specific. The paired kink is the DT-specific fingerprint: topology should affect not only accumulation or boundary localization, but also the operational cost of erasure and forgetting.

**Falsification condition.** A controlled dissipative topological system crosses a confirmed topological phase boundary while both  $\dot{\Sigma}_{\text{ss}}(\gamma)$  and  $\kappa(\gamma)$  remain analytic after finite-size, boundary, disorder, and noise artifacts are excluded.

**Required next work.** Define operational forgetting rate in a platform-specific way, such as decay of reconstructability of an initial boundary-localized state, loss of recoverable winding information under local noise, or minimal erasure cost to remove topological memory.

### Claim SY-1: Physical symmetries as low-maintenance invariant structures

**Tier.** C.

**Statement.** Physical symmetries are not merely formal conveniences; they are low-maintenance structures that survive pruning, coarse-graining, and repeated representation changes. Under finite distinguishability and

active pruning pressure, symmetric configurations are selectively preserved because they require fewer distinct update operations to maintain. This selects for invariance rather than complexity.

**Dependencies.** Invariant-supported persistence (TP-1); finite distinguishability; active pruning.

**Prior-art relation.** Noether's theorem links symmetries to conservation laws [40]. DT does not contradict this. It proposes an upstream reason: symmetries are low-cost invariant structures favored by finite distinguishability and pruning pressure, which explains why conservation laws appear at all.

**Not claimed.** The specific gauge group of the Standard Model or the number of observed symmetries.

**Falsification condition.** A physical system with active pruning and finite distinguishability shows no preference for symmetric configurations over asymmetric ones under equivalent maintenance cost.

## HIGH-RISK INTERPRETIVE EXTENSIONS

The claims in this section are not required by the FDS Core, the observer-time claims, bounded-memory computation, or topological-persistence predictions. They are registered as high-risk interpretive or structural hypotheses. Failure of these claims does not affect any earlier claim family.

### FERMION GENERATIONS AND CP/T-ASYMMETRIC IDENTITY TRANSFORMATION

#### Prior-art boundary

The Kobayashi-Maskawa mechanism showed that CP violation in a CKM-type quark-mixing sector requires at least three generations [28]. In general, an  $N$ -generation CKM matrix has  $(N-1)(N-2)/2$  physical CP-violating phases; for  $N=2$  this number is zero, and for  $N=3$  it is one. Precision electroweak, Higgs, flavor, and cosmological constraints strongly constrain ordinary sequential fourth-generation scenarios [29].

#### Claim FG-1: CKM lower-bound recovery

**Tier.** B.

**Statement.** If microscopic identity transformation requires an irreducible CP/T-asymmetric channel, and if this channel is realized through CKM-type unitary flavor mixing, then algebraic phase counting requires  $N_{\text{gen}} \geq 3$ .

**Prior-art relation.** DT does not claim to discover the CKM lower bound. It reinterprets the lower bound as

a possible finite-system necessity for irreversible identity transformation.

**Novel DT contribution.** The CKM lower bound is placed inside the chain

$$\begin{aligned} \text{active pruning} &\rightarrow \text{microscopic irreversibility} \\ &\rightarrow \text{CP/T-asymmetric channel} \rightarrow N_{\text{gen}} \geq 3. \end{aligned} \quad (4)$$

**Falsification condition.** A CKM-type unitary flavor-mixing sector with physical CP violation and only two generations would falsify the algebraic bridge. A non-CKM CP mechanism would not falsify the claim but would limit its scope.

#### Claim FG-2: Active pruning requires microscopic asymmetry

**Tier.** C / high-risk.

**Statement.** A physical world that permits irreversible identity transformation or selective pruning requires microscopic CP/T-asymmetric channels.

**Novel DT contribution.** CP/T asymmetry is interpreted not merely as a parameter of weak interactions but as a candidate physical carrier of irreversible identity transformation.

**Falsification condition.** A complete physical account of irreversible identity transformation with no microscopic CP/T-asymmetric channel, no environmental arrow, and no compensating asymmetry would demote this claim.

#### Claim FG-3: Thermodynamic minimality of three generations

**Tier.** C / high-risk.

**Statement.** More than three ordinary sequential generations may introduce redundant distinguishability channels and maintenance cost without improving minimal CP/T-asymmetric closure; thus  $N=3$  may be thermodynamically minimal.

**Status.** This is not a theorem. It is a high-risk physical bridge conjecture.

**Falsification condition.** Discovery of a fourth ordinary sequential fermion generation compatible with electroweak, CKM, Higgs, and cosmological constraints would strongly demote this conjecture.

**Required next work.** A free-energy or distinguishability functional over flavor-sector complexity that penalizes redundant CP channels and predicts  $N=3$  as an optimum, not merely as an observed fact.

## FUNCTIONAL DECOMPOSITION OF THE FOUR FUNDAMENTAL INTERACTIONS

### Claim FF-1: Four interactions as minimal finite-distinction operations

**Tier. C** (high-risk interpretive).

**Statement.** The four observed interactions correspond to four minimal operations required by finite distinguishability:

strong interaction	encapsulation / confinement,
electromagnetic	long-range Abelian connection,
weak interaction	identity transformation / pruning,
gravity	horizon-geometric maintenance.

**Not claimed.** This is not a derivation of  $SU(3)_c \times SU(2)_L \times U(1)_Y$ , coupling constants, masses, renormalization flows, or spontaneous symmetry breaking.

The four-interaction mapping is an isomorphism-seeking interpretive bridge. It is not a derivation of the Standard Model gauge group, coupling constants, field content, or renormalization structure.

**Novel DT contribution.** The interactions are interpreted functionally as finite-distinction operations rather than merely as forces acting on particles.

**Falsification condition.** A discovered fundamental interaction that cannot be mapped onto encapsulation, connection, identity transformation, or horizon-geometric maintenance under rigid criteria would challenge the completeness of the decomposition.

### Claim FF-2: No unscreened long-range non-Abelian connection force

**Tier. B+/C.**

**Statement.** A universal long-range connection channel must be path-independent, composable, and effectively Abelian. Any non-Abelian sector in the low-energy physical world must be confined, Higgsed, screened, or strongly suppressed.

**Prior-art relation.** QCD is non-Abelian but confined at low energy; weak interactions are non-Abelian but Higgsed. The DT claim is a functional interpretation of why non-Abelian structure does not appear as a universal unscreened macroscopic connection channel.

**Falsification condition.** Discovery of an unscreened, massless, long-range, non-Abelian fundamental force with macroscopic  $1/r$ -type behavior and non-negligible coupling would falsify the strong version.

### Claim FF-3: Weak identity transformation requires irreducible CP/T-asymmetric invariant

**Tier. C.**

**Statement.** A complete weak-like identity-transforming sector must contain an irreducible CP/T-asymmetric invariant, though individual processes may be CP-conserving.

**Falsification condition.** Discovery of a complete flavor-changing, identity-transforming fundamental sector with weak-scale coupling and no irreducible CP/T-asymmetric invariant would undermine the claim.

### Claim FF-4: Gravity as horizon-geometric maintenance, not ordinary internal gauge force

**Tier. C.**

**Statement.** Gravity is not merely one more internal gauge operation. It is the effective geometry of finite causal-access maintenance.

**Interpretive value.** This claim explains why gravity couples universally to stress-energy rather than to a particular internal charge. Anything that changes distinguishability density or causal accessibility enters the geometry ledger.

## PAULI EXCLUSION AND FINITE ADDRESS PROTECTION

### Claim PX-1: Pauli exclusion as finite distinguishability address protection

**Tier. D/C.**

**Statement.** Pauli exclusion may be interpreted as finite-address protection: two indistinguishable fermionic distinction records cannot occupy the same physical address without identity collapse.

**Prior-art relation.** This does not replace the spin-statistics theorem or quantum field theoretic derivations of fermionic antisymmetry [30, 31]. It is an interpretive bridge from exclusion to finite distinguishability.

**Falsification condition.** A regime in which identical fermions stably violate exclusion while preserving all relevant quantum statistics and no compensating structure appears would undermine the interpretive bridge.

**Status.** High-risk interpretive claim. It should not be used as a primary physical prediction until mathematically connected to spin-statistics.

**Limitation.** This claim is not an explanatory substitute for the spin-statistics theorem. It is a proposed upper-level interpretation of why an antisymmetric fermionic address structure is useful for finite distinguishability. Until a functorial or algebraic map is constructed from fermionic antisymmetry to finite-address protection, PX-1 remains an interpretive bridge only.

## MASS-ENERGY CONVERTIBILITY AND STORED DISTINCTION

### Claim ME-1: Mass as localized invariant-supported distinction storage

**Tier. C.**

**Statement.** Mass can be interpreted as localized, stable, invariant-supported distinction storage.

**Interpretation.** A massive structure is not merely energy at rest; it is a persistent local carrier of physically addressable distinctions.

**Not claimed.** This is an interpretive bridge, not a derivation of  $E = mc^2$  or relativistic mass-energy equivalence.

### Claim ME-2: Energy as distinction-update capacity

**Tier. C.**

**Statement.** Energy is the capacity to update, transform, maintain, or release physical distinctions.

**Not claimed.** This is an interpretive bridge, not a derivation of thermodynamic energy definitions or conservation laws.

### Claim ME-3: Mass-energy convertibility

**Tier. C.**

**Statement.** If mass is stored distinction structure and energy is update capacity, then conversion between mass and energy expresses the convertibility of stored structure and executable update capacity.

**Not claimed.** This is an interpretive bridge, not a derivation of  $E = mc^2$  or relativistic mass-energy equivalence.

**Prior-art relation.** Relativity already explains mass-energy equivalence once Lorentz symmetry and invariant causal speed are assumed [32]. Distinction Theory does not replace that derivation.

**Limitation.** DT does not derive  $E = mc^2$  unless the invariant causal speed and Lorentz-type structure are independently recovered.

## CLAIM DEPENDENCY MAP

Table I summarizes the dependency logic. The most important point is that failure propagates locally. If the dark-energy module fails, the topological-persistence module may survive. If the Pauli interpretation fails, the observer/time claims may survive. The registry is not a single all-or-nothing claim.

## Dependency DAG

High-risk claims are downstream and do not affect upstream core claims if they fail. The dependency structure is summarized below.

**Level 0 (Core):** FDS Core.

**Level 1 (Physical Bridge):** finite distinguishability (PB), Landauer bridge, finite causal access.

**Level 2 (Core-Derived):**

- observer register (OT-1) → operational time (OT-2), finite causal access (OT-3)
- bounded-memory computation (BC-1)
- invariant-supported persistence (TP-1) → topological obstruction (TP-2) → two-kink signature (TP-3)

**Level 3 (High-Risk or Interpretive):**

- horizon thermodynamics (HT-1, HT-2) → dark energy (DE-1, DE-2, DE-3)
- CP/T asymmetry (FG-1, FG-2, FG-3)
- functional decomposition (FF-1, FF-2, FF-3)
- Pauli interpretation (PX-1)

## EXPERIMENTAL ROADMAP: TEST MATURITY LADDER

### Level 1: Conceptual audit

**Observer as finite distinction-register.** Clarify operational definition of observer in terms of finite record carrier, distinguishability budget, and boundary maintenance.

**Operational time.** Define ordered irreversible distinction update in terms of Landauer erasure cost and record stability.

**Finite causal access.** Formalize maximum causal update rate from finite distinguishability.

### Level 2: Simulation-ready

**Active-pruning AI benchmark.** Although not a physical test, it is the nearest operational test of the finite-system architecture. Compare passive accumulation, bounded memory, active pruning, and causal loop closure on long-horizon tasks with explicit resource budgets.

**Bounded-memory reversible computation.** Build or simulate finite-memory reversible circuits under continuous input/output streams. Measure garbage accumulation, reset frequency, and dissipated heat. The

Claim family	Depends on	Risk	Failure consequence
Observer/time	finite distinction registration	medium	revises observer/time module
Landauer bridge	irreversible erasure thermodynamics	medium	demotes L1b physical bridge
Causal speed	finite causal access	high	revises relativity bridge only
Horizon/gravity	finite causal access + entropy bounds	high	revises gravity module
Dark energy	horizon maintenance scaling	high	demotes DE module
Topological persistence	invariant-supported structure	medium	revises TP module
Two-kink prediction	dissipative topological testbed	medium-high	strongest TP falsifier
Fermion lower bound	CP/T + CKM-type mixing	medium	revises FG bridge scope
Fermion exact-three	thermodynamic minimality	high	demotes upper-bound conjecture
Four forces	functional operation decomposition	high	demotes FF module
Pauli bridge	finite address protection + spin-statistics link	high	remains interpretive only

TABLE I. Dependency and failure propagation map for major physical claim families.

target is not to refute reversible computing but to test the bounded-memory housekeeping claim.

**Finite truncation effective stochasticity.** Develop numerical models showing that finite distinguishability alone produces operational stochasticity in reduced descriptions.

### Level 3: Experimental proxy

**NHSE two-kink experiment.** In a non-Hermitian topological system, tune through a confirmed topological transition and measure both entropy production and operational forgetting rate. The falsification target is paired analyticity where DT predicts aligned kinks.

**Analogue-horizon Landauer kink.** Use BEC, optical, acoustic, or circuit analogue systems to tune effective horizon conditions and measure entropy-production or mode-registration anomalies near capacity-like transitions [17, 18]. Note: this is a proposed experimental proxy, not yet a DT-specific prediction.

**Entropy-production finite-system bound.** Measure boundary-maintenance entropy production in controlled finite systems and compare against theoretical lower bounds.

### Level 4: Observational cosmology

**Dark-energy equation-of-state constraints [HIGH-RISK].** DESI, Euclid, Roman, and CMB-S4 will continue constraining  $w(z)$ . DT requires a more precise model before its dark-energy claim can be sharply separated from ordinary quintessence, phantom, HDE/RDE, and modified-gravity alternatives.

**Gravitational-wave propagation or ringdown anomalies [HIGH-RISK].** If gravity is horizon maintenance, far-from-equilibrium horizon events may produce tiny non-GR signatures. Astrophysical signals may be too small, but standard sirens and third-generation detectors may constrain the space.

### Level 5: High-risk structural physics

**Fermion-sector extensions [HIGH-RISK].** Precision flavor physics and searches for fourth-generation or vector-like fermions constrain the exact-three conjecture. Discovery of an ordinary sequential fourth generation would strongly demote the thermodynamic-minimality claim.

**Four-force functional decomposition [HIGH-RISK].** Develop quantitative mapping from finite-distinction operations to observed interaction sectors.

**Pauli address protection [INTERPRETIVE].** Construct functorial or algebraic map from fermionic antisymmetry to finite-address protection before promoting to physical prediction.

### WHAT WOULD COUNT AS SUCCESS?

#### Weak success

Weak success means the registry clarifies the claim-space: which physical ideas follow from which assumptions, what is prior art, what is novel, and what would fail if a claim is wrong.

#### Moderate success

Moderate success means at least one physical bridge claim generates a test protocol not already standard in the relevant field. Candidate examples are the bounded-memory reversible-computation dissipation test and the analogue-horizon Landauer-kink test.

#### Strong success

Strong success means a DT-specific prediction is confirmed. The clearest candidates are:

- paired entropy-production and forgetting-rate kinks at a topological transition (TP-3);
- analogue-horizon maintenance-cost kinks, if a DT-specific observable is defined;
- bounded-memory open-ended reversible computation showing unavoidable reset/pruning dissipation scaling (BC-1).

Dark energy remains a high-risk candidate requiring a concrete  $w(z)$  model before it can be sharply tested against alternatives.

### Transformative success

Transformative success would require multiple independent physical domains to exhibit the same structural signature:

finite boundary  $\rightarrow$  maintenance cost  $\rightarrow$  pruning / collapse / invariant persistence.

At that point, DT would no longer be merely a registry of physical bridges. It would become a candidate organizing principle for finite physical systems.

Such convergence would support the view that the thermodynamic cost of distinguishability is a fundamental constraint on physical evolution across finite systems.

## DISCUSSION

### Why a registry is scientifically useful

A broad physical programme is easy to overstate. It is also easy to dismiss. A registry format avoids both failure modes. It states claims in a way that can be indexed, challenged, and revised. It also clarifies which claims are original and which are reinterpretations of established physics.

In this registry, horizon thermodynamics is not new; the DT contribution is the finite-distinction interpretation. CKM phase counting is not new; the DT contribution is the active-pruning-to-CP/T bridge. NHSE is not new; the DT contribution is the two-kink forgetting/entropy fingerprint. Landauer erasure is not new; the DT contribution is its integration into a finite-system maintenance-cost chain.

### The strongest and weakest modules

The strongest modules are those with explicit observables and clear prior-art interfaces: bounded-memory computation, Landauer accounting, topological persistence, and the two-kink experiment. The weakest modules are those that currently remain interpretive: Pauli

address protection, exact-three thermodynamic minimality, and the full four-force functional decomposition. Dark energy has high potential but also high model-selection risk.

### What this paper does not do

This paper does not compute a Lagrangian, derive field equations, solve quantum gravity, or claim that all physical constants are fixed by distinction alone. It also does not claim that existing physics is wrong. In many cases, DT aims to explain why existing structures might be necessary under finite-system constraints, not to replace the successful equations that already describe them.

## CONCLUSION

This paper has registered a dependency-ordered physical claim-space for Distinction Theory. The registry begins from finite distinguishability, irreversible distinction updates, finite causal access, and the Landauer bridge. It then organizes physical extensions into observer/time, bounded computation, horizon/gravity, dark energy, topological persistence, fermion generations, four interaction functions, Pauli exclusion, and mass-energy convertibility.

The result is not a completed physics. It is an auditable map. Some claims reinterpret known structures: Landauer erasure, horizon thermodynamics, Bekenstein bounds, CKM phase counting, and invariant persistence. Others propose testable extensions: a topological two-kink signature, analogue-horizon maintenance kinks, horizon-maintenance dark energy, and bounded-memory reversible-computation dissipation. These vary substantially in risk, from near-term conservative tests to high-risk cosmological hypotheses. Each claim is assigned a scope and a death condition.

The registry's value is therefore not that every claim is already true. Its value is that the physical extension of FDS is no longer an undifferentiated speculative cloud. It is a dependency-ordered, failure-aware, and updateable claim-space.

The author thanks all those who provided critical feedback on earlier drafts. The author used AI-assisted editing tools for language polishing, structural feedback, and draft preparation. All claims, arguments, citations, and final wording were reviewed and approved by the author.

## Appendix A: Full Claim Registry Tables

TABLE II. Core and medium-risk physical claims.

ID	Claim	Tier	Key prediction	Falsifier
OT-1	Observer as finite distinction-register	B	Observer requires finite record carrier	Observer-independent registered state with no finite carrier
OT-2	Time as irreversible distinction update	B/B+	Erased records cannot recur without entropy compensation	Entropy-free restoration of erased accessible record
OT-3	Finite and invariant causal speed	C/B	Finite observers require invariant causal update bound	Operational infinite causal access without inconsistency
BC-1	Bounded-memory reversible computation dissipates	B+	Open-ended finite computation requires reset/pruning	Zero-dissipation bounded open-ended computation
HT-1	Horizon as distinguishability boundary	B	Horizons track finite causal access	Horizon independent of access/information constraints
HT-2	Gravity as horizon maintenance geometry	C/B	GR-like geometry as equilibrium limit	Complete gravity with no horizon/information role
HT-3	Non-equilibrium horizon corrections	B+/C	Far-from-equilibrium horizons show maintenance anomalies	No anomaly in controlled non-equilibrium horizon test
DE-1	$\rho_{DE} \sim H^2 M_{Pl}^2$	C/B+	Horizon-maintenance dark-energy scale	Data selects incompatible dark-energy model
DE-2	$10^{-122}$ as area suppression	C	$\rho_{DE}/\rho_{Pl} \sim (t_P/R_H)^2$	Scaling shown physically irrelevant
TP-1	Invariant-supported persistence	B	Global invariants reduce maintenance burden	Invariants erased locally without transition or cost
TP-2	Topological obstruction to forgetting	B+	Local forgetting cannot erase global invariant cheaply	Local Markovian forgetting erases invariant completely
TP-3	Two-kink signature	B+	Entropy and forgetting kinks align at $\gamma_c$	No kinks at confirmed topological transition
FG-1	CKM lower-bound recovery	B	CP/T CKM channel requires $N_{gen} \geq 3$	CKM-type CP with two generations
FF-2	No long-range non-Abelian connection force	B+/C	Non-Abelian sectors confined/Higgsed/screened	Unscreened massless long-range non-Abelian force
ST-1	Effective stochasticity from finite truncation	C/B	Finite reduced descriptions produce operational stochasticity	Bounded observer tracks all relevant degrees without residual uncertainty
QG-1	Horizon as finite-distinguishability access boundary	C/B	BH horizon is distinguishability boundary for finite observer	Horizon with no relation to causal access or distinguishability
BH-1	Boundary encoding vs finite observer recoverability	C	Information may be globally preserved but operationally inaccessible	Complete recovery of BH information by any finite observer
PI-1	Particle species as invariant-supported identity classes	C	SM particle content as invariant identity classes	Particle species with no invariant-supported identity structure
DM-2	Stability of dark-matter candidates	C	DM must be stable low-dissipation identity carrier	Dark matter with no stable identity structure
QM-1	Measurement as finite record stabilization	C	Measurement stabilizes reproducible distinction record	Record stabilization without any finite carrier
QM-2	Classical outcome as stable distinction record	C	Classicality from record stability across multiple observers	Classical outcome with no distinction record stability
QM-3	Global unitary vs finite observer update	C	Unitary global evolution compatible with irreversible local record update	Contradiction between unitarity and finite-record thermodynamics
GT-1	Gauge redundancy as description-equivalence quotient	C	Gauge symmetry as quotient over equivalent distinction descriptions	Gauge symmetry with no redundancy quotient interpretation
CMB-1	CMB as Phase-B cosmological residue	C	CMB is persistent record of early-universe distinction structure	CMB with no relation to distinction structure
CA-1	Cosmological arrow as record asymmetry	C	Arrow of time from finite-observer record asymmetry	Arrow of time without finite-observer record asymmetry
FR-1	Freeze-out as distinction stabilization	C	Freeze-out stabilizes distinction structure across cooling expansion	Freeze-out mechanism independent of distinction structure

TABLE III. High-risk, interpretive, and speculative extensions.

ID	Claim	Tier	Key prediction	Falsifier
DE-3	$w(z) > -1$ horizon-maintenance evolution	B+ (high-risk)	Dynamical DE approaching $-1$	$w = -1$ locked or incompatible phantom crossing
FG-2	Active pruning requires microscopic asymmetry	C (high-risk)	Identity transformation needs CP/T channel	Irreversible identity transformation with no asymmetry
FG-3	Exact three as thermodynamic minimality	C (high-risk)	No ordinary fourth sequential generation	Confirmed ordinary fourth generation
FF-1	Four interactions as finite-distinction operations	C	Four functional classes of interaction	New force outside all four rigid classes
FF-3	Weak identity transformation requires CP/T invariant	C	Weak-like sector contains irreducible CP/T invariant	Weak-like complete sector with no such invariant
PX-1	Pauli as finite address protection	D/C	Exclusion protects distinguishability address	Stable exclusion violation with fermionic statistics intact
ME-1	Mass as stored distinction	C	Mass stores stable local distinctions	No structural interpretation possible
ME-2	Energy as update capacity	C	Energy updates/maintains distinctions	No relation between energy and physical update capacity
ME-3	Mass-energy convertibility	C	Stored structure converts to update capacity	Relativity/QFT-compatible counterexample
SY-1	Physical symmetries as low-maintenance invariants	C	Symmetries favored by pruning pressure	No preference for symmetric over asymmetric configurations under equivalent cost
QD-1	Decoherence as distinguishability leakage	C	Environment drains coherence via distinguishability exchange	Persistent coherence despite verified distinguishability-leakage coupling
QC-1	Quantum computation barriers from pruning cost	D/C	Error-correction overhead creates maintenance-cost constraints	Fault-tolerant QC with sub-polynomial overhead scaling
ML-1	Mathematical form as invariant compression	D	Physics is mathematical because it's low-maintenance invariant	Successful physics requires non-invariant, non-compressible descriptions
BH-2	Page-curve compatibility	D/C	Page curve compatible with finite-observer recoverability bound	Page curve with no FDS-compatible distinguishability model
MS-1	Mass as identity-maintenance cost	C/D	Mass is cost of stable identity-class maintenance	Mass with no identity-maintenance interpretation
YK-1	Yukawa couplings as identity-transformation weights	D/C	Yukawa weights set CP/T-asymmetric identity-transform channel strengths	Yukawa structure with no identity-transformation interpretation
DM-1	Dark matter as low-addressability distinction residue	C/D	DM is stable low-dissipation identity carrier with weak EM addressability	Particle DM fully excluded without FDS-compatible residue candidate
DM-3	Effective-geometry dark-matter alternative	D	Geometry alternative to particle DM if direct detection excludes candidates	Direct detection confirms particle DM with no geometric alternative needed
BR-1	Born-rule bridge (prospective)	D	Born rule requires probability-geometry map; not yet derived	Complete Born-rule derivation from FDS principles achieved or impossible
YM-1	Confinement as boundary encapsulation	D/C	Confinement is boundary encapsulation of non-extractable color distinctions	Confinement mechanism with no FDS interpretable cost structure
YM-2	String tension as maintenance cost	D/C	Linear string tension is growing cost of separated color identity	String tension with no FDS interpretable cost structure
MG-1	Mass gap as minimum distinction cost	D/C	YM mass gap is minimum cost of nontrivial stable gauge distinction	Mass gap established with no relation to excitation cost
CI-1	Low-entropy initial condition	C/D	Low initial entropy $\equiv$ low realized macroscopic distinction complexity	Initial condition mechanism independent of distinction complexity
IN-1	Inflation as distinction dilution	D	Inflation dilutes pre-existing distinctions while seeding new structure	Inflation mechanism with no FDS interpretation

## Appendix B: Glossary

**Distinction:** The primitive act of separating what is from what is not.

**Finite distinguishability:** The condition that a physical system can register only finitely many operationally usable distinctions.

**Boundary maintenance:** The ongoing process by which a system preserves the distinction between self and environment.

**Capacity deficit:** The gap between environmental predictive demand and internal modeling budget.

**Corrective complexity:** Accumulated internal structure produced by patches, model updates, and corrections to approximation error.

**Active pruning:** Selective, energy-consuming removal, compression, or reorganization of inert complexity to preserve viability.

**Invariant-supported persistence:** Persistence through structures whose identity is carried by global invariants, symmetries, topological classes, or conserved quantities.

**Landauer bridge:** The physical bridge from logically irreversible erasure to thermodynamic entropy cost.

**Operational time:** Ordered irreversible update of accessible distinctions.

**Horizon:** Observer-relative causal distinguishability boundary.

**Two-kink signature:** Paired nonanalytic behavior in entropy production and forgetting rate at the same topological transition.

## Appendix C: Full Claim-Space Archive

The complete claim-space edition of Distinction Theory, including physical, biological, cognitive, artificial-agency, and civilizational extensions, is archived as:

Wu, Y. *Distinction Theory: A General Theory of Finite Systems*. Zenodo, 2026. DOI: 10.5281/zenodo.20130174.

### Validity Boundary for Interpretive Quantum Claims

The interpretive claims PX-1, ST-1, QD-1, QC-1, and ML-1 should not be read as replacements for the mathematical structures of quantum theory. PX-1 does not replace the spin-statistics theorem; ST-1 does not derive Bell-inequality violation or the Born rule; QD-1 does not solve the measurement problem; QC-1 does not deny the threshold theorem of fault-tolerant quantum computation; and ML-1 does not derive mathematics from physics. These claims register finite-system interpretations and possible bridge directions. Their failure would demote the relevant interpretive module without threatening the observer/time, Landauer, horizon, or topological claims.

### Appendix D: Extended High-Risk Physical Bridge Claims

The claims in this section are registered as high-risk interpretive or structural hypotheses. They are not required by the FDS Core or by claims in earlier sections. Failure of these claims does not affect any earlier claim family. Each claim follows the registry template: ID, Tier, Statement, Dependencies, Prior-art relation, Novel DT contribution, Not claimed, Falsification condition, Required next work.

#### Quantum gravity and black-hole information

*Claim QG-1: Horizon as finite-distinguishability access boundary.* Tier C/B. A black-hole horizon is a finite-distinguishability access boundary: the point beyond which distinctions cannot be registered, updated, or operationally used by an external finite observer. This extends HT-1 to the strong-gravity regime.

*Claim BH-1: Boundary encoding versus finite observer recoverability.* Tier C. FDS separates global distinction preservation from finite observer recoverability. Information may be preserved globally (in the full physical state) while being inaccessible to any finite observer with bounded causal access. This does not imply information loss; it separates the ontological claim from the operational one.

*Claim BH-2: Page-curve compatibility.* Tier D/C. The Page curve and island formulae are compatible with FDS if the finite observer's recoverable information is bounded by its causal access and distinguishability budget. Required future work: embed island formulae in an FDS distinguishability framework.

*Not claimed.* FDS does not provide a microscopic quantum-gravity model, derive the Page curve, solve the firewall problem, or replace semiclassical gravity.

#### Particle identity, mass, and coupling structure

*Claim PI-1: Particle species as invariant-supported identity classes.* Tier C. Observed particle species correspond to stable, invariant-supported identity classes under finite distinguishability constraints. The Standard-Model particle content is one realization of this principle.

*Claim MS-1: Mass as identity-maintenance cost.* Tier C/D. Mass is the maintenance cost of a stable identity class under finite distinguishability: a massive particle requires persistent distinction updates to maintain its identity across propagation.

*Claim YK-1: Yukawa couplings as identity-transformation channel weights.* Tier D/C. Yukawa couplings set the relative strength of identity transformation between fermion species. In FDS terms, they weight the CP/T-asymmetric identity-transformation channels. Derivation from FDS principles is not yet available.

*Not claimed.* FDS does not derive Standard-Model gauge groups, coupling constants, mass values, the Higgs mechanism, or Yukawa matrix structure.

#### Dark matter

*Claim DM-1: Dark matter as low-addressability gravitational distinction residue.* Tier C/D. Dark matter is a stable, low-dissipation identity carrier that participates in gravitational boundary conditions while remaining weakly addressable through electromagnetic distinction channels.

*Claim DM-2: Stability of dark-matter candidates.* Tier C. Any viable dark-matter candidate must be a stable, low-dissipation identity carrier under finite-system pruning and maintenance pressures. This is consistent with WIMP, axion, and sterile-neutrino scenarios but does not select among them.

*Claim DM-3: Effective-geometry alternative.* Tier D. If particle dark matter is excluded by future direct-detection and collider constraints, an effective-geometry alternative (modification of horizon-scale gravitational distinction) remains open. This is registered as a speculative placeholder, not a prediction.

*Not claimed.* FDS does not identify the dark-matter particle, predict its mass, or claim that modified gravity is correct.

### Quantum measurement and records

*Claim QM-1: Measurement as finite record stabilization.* Tier C. A quantum measurement is the process by which a finite distinction-register stabilizes a reproducible record from a superposed or entangled state. The outcome is classical insofar as it is a stable, reproducible distinction record.

*Claim QM-2: Classical outcome as stable distinction record.* Tier C. Classicality arises from record stability across multiple finite observers, not from collapse of the wavefunction alone. A result that can be registered, preserved, and communicated by bounded observers is operationally classical.

*Claim QM-3: Global unitary evolution versus finite observer record update.* Tier C. The global quantum state may evolve unitarity while the finite observer's record undergoes irreversible distinction update. This resolves no contradiction between unitary quantum mechanics and finite-record thermodynamics.

*Claim BR-1: Born-rule bridge.* Tier D. A derivation of the Born rule from FDS principles is not yet available. A future bridge would require a probability-geometry map linking distinction-count ratios to measurement outcome frequencies. This remains prospective.

*Not claimed.* FDS does not solve the quantum measurement problem, derive the Born rule, violate Bell inequalities operationally, or replace standard decoherence theory.

### Confinement and mass gap

*Claim YM-1: Confinement as boundary encapsulation.* Tier D/C. Confinement in non-Abelian gauge theory corresponds to boundary encapsulation of non-extractable color distinctions. Color charge cannot be isolated because the cost of separating color-distinct states grows with distance, consistent with a maintenance-cost interpretation.

*Claim YM-2: String tension as maintenance cost.* Tier D/C. The linear string tension in QCD is the growing maintenance cost of maintaining separated color-distinct identity carriers. This is consistent with lattice QCD but adds an FDS interpretation.

*Claim MG-1: Mass gap as minimum distinction cost.* Tier D/C. The Yang–Mills mass gap is the minimum excitation cost of a nontrivial stable distinction in the gauge field. An FDS model would need to show this cost is positive and finite.

*Claim GT-1: Gauge redundancy as description-equivalence quotient.* Tier C. Gauge symmetry is the quotient over physically redundant descriptions of the same distinction structure. This does not replace gauge theory but provides an upstream interpretation.

*Not claimed.* FDS does not solve the Yang–Mills Millennium Problem, derive the mass gap, compute the string tension, or replace QCD.

### Cosmological initial conditions and relic records

*Claim CI-1: Low-entropy initial condition.* Tier C/D. The low-entropy initial condition of the universe corresponds to low realized macroscopic distinction complexity. The early universe had few distinguishable macroscopic configurations.

*Claim IN-1: Inflation as distinction dilution.* Tier D. Inflation dilutes pre-existing distinctions across horizon scales while seeding new small-scale distinction structure through quantum fluctuations. This is consistent with standard inflationary cosmology but adds no new mechanism.

*Claim CMB-1: CMB as Phase-B cosmological residue.* Tier C. The cosmic microwave background is a stabilized, persistent record of early-universe distinction structure—a Phase-B cosmological residue in FDS terms.

*Claim CA-1: Cosmological arrow.* Tier C. The cosmological arrow of time is the record asymmetry produced by finite observers embedded in an expanding, cooling universe with irreversible distinction updates.

*Claim FR-1: Freeze-out as distinction stabilization.* Tier C. Freeze-out of particle species and relic abundances across cosmic expansion is the stabilization of distinction structure as the universe cools and dilutes.

*Not claimed.* FDS does not replace inflationary cosmology, predict the primordial power spectrum, derive the baryon asymmetry, or solve the flatness/horizon problems without existing mechanisms.

### Appendix E: Additional Interpretive Bridge Claims

#### Claim ST-1: Effective stochasticity from finite truncation

**Tier.** C/B.

**Statement.** When a finite observer or finite subsystem coarse-grains inaccessible degrees of freedom, the discarded variables appear as effective stochasticity in the reduced description. This claim concerns operational stochasticity in finite descriptions, not a replacement for the Born rule, Bell nonlocality, or the full quantum measurement problem.

**Dependencies.** Finite distinguishability; capacity deficit; approximation; observer-relative boundary.

**Prior-art relation.** Statistical mechanics derives stochasticity from many degrees of freedom. DT proposes an additional upstream source: finite distinguishability alone, even with a single degree of freedom, forces lossy truncation that appears as effective stochasticity to an observer with bounded access.

**Scope limitation.** ST-1 does not claim that all microscopic quantum randomness is merely classical ignorance or hidden variable truncation. In particular, it does not by itself derive Bell-inequality violation, the Born rule, or contextuality. Those require separate quantum-bridge assumptions.

**Boundary.** ST-1 concerns the general effective stochasticity produced by any finite system’s truncation of inaccessible degrees of freedom, covering classical algorithmic and statistical contexts. In the quantum regime, when environmental degrees of freedom exceed the system’s tracking capacity, this distinguishability leakage is instantiated as quantum decoherence, addressed separately in QD-1.

**Falsification condition.** A finite observer with demonstrably bounded access that can nevertheless track all causally relevant degrees of freedom of a reduced system without residual uncertainty, stochastic coarse-graining, hidden environmental dependence, or measurement back-action would undermine the operational version of this claim.

#### Claim QD-1: Decoherence as environmental distinction leakage

**Tier.** C.

**Statement.** Quantum decoherence is reinterpreted as the leakage of distinguishability information into the environment. A system’s quantum coherence requires maintaining superpositions as distinguishable internal states. When the environment continuously interacts with and entangles those states, distinguishability leaks outward, destroying internal coherence. Decoherence rate is thus a measure of distinguishability exchange with the environment.

**Dependencies.** Finite distinguishability; boundary maintenance; environment as distinguishability sink.

**Prior-art relation.** Decoherence theory is standard [36]. This registry proposes that decoherence rate has an interpretation in terms of distinguishability exchange, complementing the standard environmental entanglement view.

**Limitation.** QD-1 does not solve the measurement problem or derive the Born rule. It reinterprets the standard environment-induced loss of coherence as distinguishability leakage relative to a finite boundary.

**Falsification condition.** A quantum system shows persistent coherence despite continuous distinguishability-leakage interactions with a large environment.

#### Claim QC-1: Quantum computation barriers from finite error-correction and pruning cost

**Tier.** D/C.

**Statement.** Quantum computation error-correction incurs active-pruning-like costs. Maintaining logical qubits requires continuous correction of physical qubit errors, which is a form of active complexity management. Under finite distinguishability and finite energy budgets, there exists a threshold beyond which error-correction overhead exceeds the computational advantage, creating a maintenance-cost barrier for scalable quantum computation under finite energy and error-correction budgets.

**Dependencies.** Finite distinguishability; active pruning; bounded free energy.

**Prior-art relation.** Quantum error-correction is standard [37, 38]. This registry proposes a DT-specific interpretation: error-correction is pruning at the quantum level, and finite maintenance budgets impose maintenance-cost constraints on scalable quantum computation.

**Falsification condition.** Fault-tolerant quantum computation with arbitrarily low logical error rates is achievable with overhead scaling that is sub-polynomial in the logical qubit count (e.g., constant or logarithmic).

#### Claim ML-1: Mathematical form of physical laws as invariant compression

**Tier.** D.

**Statement.** The mathematical form of physical laws is not an arbitrary human invention but an invariant compression of the underlying distinction structure. Invariant-supported structures (symmetries, conservation laws, geometrical relationships) survive repeated pruning and coarse-graining because they are the lowest-maintenance way to encode distinguishability relationships. This explains why physics is mathematical: mathematics is the language of invariant compression.

**Dependencies.** Invariant-supported persistence (TP-1); low-maintenance invariant structures (SY-1).

**Prior-art relation.** Wigner’s ”unreasonable effectiveness of mathematics” [39] is a philosophical puzzle. DT provides an operational answer: mathematical forms survive because they are low-maintenance representations of distinction structure.

**Falsification condition.** If successful physical theories systematically required non-compressible, non-invariant, representation-dependent descriptions with no stable symmetry, conservation, or geometric structure, the claim would be weakened.

**Limitation.** ML-1 is not a derivation of mathematics from physics. It is a proposed selection principle for why invariant mathematical representations are preferentially

stable under repeated model revision, coarse-graining, and pruning.

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