Finite-Distinction Operation Closure and the Four Fundamental Interactions: Encapsulation, Connection, Identity Update, and Causal-Screen Ledger Geometry

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X3 proposes a finite-distinction operation closure for the four known fundamental interactions. It does not derive the Standard Model gauge group, coupling constants, particle masses, scattering amplitudes, electroweak symmetry breaking, CKM/PMNS parameters, or quantum gravity. Its narrower claim is that any physical world containing finite distinctions that are persistent, communicable, transformable, and globally embedded requires four non-equivalent operation classes: token encapsulation, connection or remote detectability, identity-sector update, and global causal-ledger geometry. In the observed world, the strong, electromagnetic, weak, and gravitational interactions realize these primary roles respectively. The G1 finite-screen gravity program strengthens the fourth row by turning gravity from a loose "global accounting" label into causal-screen ledger geometry: finite causal-screen entropy response, Ward/Bianchi closure, Weyl-normalized residual interfaces, and finite-screen realization prototypes. X3 therefore becomes an operation-closure module in a larger FDS physics spine: X4 supplies matter-address protection, X2 supplies the oriented weak identity-update module, X3 classifies interaction operation classes, and G1 supplies the global causal-screen ledger. The mapping is primary-role, not exclusive-role. New particles, portals, dark sectors, or fifth-force candidates do not by themselves refute X3; the basis is challenged only by a fundamental interaction implementing a necessary operation primitive not reducible to encapsulation, connection, identity update, or causal-ledger geometry. A visual normal-form layer is included to display operation maps, coverage matrices, remove-one losses, fifth-force audit logic, and relation maps.

Scope and Claim Status. X3 is a functional-decomposition and operation-closure paper, not a Standard Model derivation paper. It does not derive $SU(3)_c \times SU(2)_L \times U(1)_Y$, electroweak symmetry breaking, coupling constants, masses, scattering amplitudes, CKM/PMNS parameters, or quantum gravity. It does not claim that no new particles, portals, dark sectors, fifth-force candidates, or effective interactions can exist. Its claim is narrower: the four known interactions naturally instantiate four non-equivalent physical operation classes required for finite physical distinction maintenance.

G1 firewall. X3 uses the finite-screen architecture developed in G1, not the empirical success of any particular G1DE residual branch. The G1DE-$M_{3/4}$ result strengthens the physical motivation for the gravity row, but the X3 operation-closure claim is logically distinct from the late-time cosmology evidence hierarchy.

Claim-status summary

Table I separates the main closure thesis from lower-status implementation claims and from demotion conditions.

Keywords

Finite Distinction Systems; Distinction Theory; fundamental interactions; operation closure; strong interaction; electromagnetism; weak interaction; gravity; causal-screen ledger; finite screen spacetime; G1; G1DE; Pauli exclusion; identity update; flavor change; boundary accounting; fifth-force classification.

INTRODUCTION

The interaction-taxonomy problem

The Standard Model and general relativity describe four known fundamental interactions: strong, electromagnetic, weak, and gravitational. Quantum chromodynamics describes strong color dynamics [10, 14–16]; electroweak theory describes electromagnetic and weak interactions [9–13]; general relativity describes gravity as spacetime geometry [20–22]. X3 does not replace those theories. It asks a different question: why do the known interactions occupy four qualitatively different physical roles?

The usual classification by gauge group or field content is indispensable, but it does not by itself say why a physical world maintaining finite distinctions should contain operation classes that look like encapsulation, connection, identity update, and causal geometry. X3 proposes that the four known interactions realize a minimal operation closure for finite physical distinction maintenance.

TABLE I. Central X3 claims, status, and demotion conditions.

Claim	**Status**	**What would weaken, demote, or falsify it**
Finite physical distinctions require stable material tokens.	Operational requirement	Persistent matter-like records exist without any encapsulation, binding, exclusion, or protection mechanism.
Strong interaction realizes the hadronic/baryonic encapsulation role.	Physical mapping	Hadronic stability is explained while confinement and color-neutral binding play no token-stabilizing role.
Finite physical distinctions require connection and remote detectability.	Operational requirement	Complex persistent structures, sensing, and communication exist without any mediating connection channel.
Electromagnetism realizes ordinary long-range connection.	Physical mapping	Electromagnetism is shown not to underwrite ordinary atomic, chemical, radiative, sensing, or communication structure.
Finite physical distinctions require identity-sector update.	Operational requirement	Physical identity sectors never require decay, conversion, pruning, or controlled transformation.
Weak interaction realizes flavor-changing identity update.	Physical mapping	Flavor change, beta decay, and weak identity-sector conversion are realized by a different fundamental carrier.
Gravity realizes global causal-screen ledger geometry.	G1-strengthened bridge	Gravity is shown to be unrelated to causal structure, horizons, stress-energy accounting, finite-screen entropy response, or global boundary constraints.
Four interactions form a minimal operation closure.	Main X3 thesis	A fundamental interaction implements a necessary operation primitive not reducible to encapsulation, connection, identity update, or causal-ledger geometry.

From functional taxonomy to operation closure

Earlier X3 versions emphasized a functional decomposition of the four interactions. That framing is useful and remains pedagogically valuable. The G1-era strengthening turns the paper into an operation-closure module: the question is not merely how to label the four interactions, but why finite physical distinctions require four non-equivalent operation primitives.

The shift is:

$$\text{functional taxonomy} \longrightarrow \text{finite-distinction operation closure.} \tag{1}$$

In this version, the old visual and normal-form material is retained, but the canonical claim is the stronger closure statement.

G1-era strengthening of the gravity row

Earlier X3 drafts described gravity as global boundary, causal geometry, and stress-energy accounting. G1 strengthens this row. In G1, the primitive gravitational object is a finite causal-screen entropy functional

$$S_{\rm scr} : X_{\rm phys} \to \mathbb{R}, \tag{2}$$

whose response one-form, local area response, capacity-flow normal forms, all-null metric envelope, Ward/Bianchi closure, Weyl-normalized residuals, and finite-screen realization prototypes provide a structured bridge from finite screen ledgers to gravity-like geometry [8].

Thus the gravity row in X3 is not merely a relabeling of GR. It is the operation-class face of the G1 response chain:

$$S_{\rm scr} \to \omega \to \eta_{\rm loc} \to G_{\rm loc}^{-1} \to \theta\text{-flow} \to \text{metric envelope} \to \text{residuals.} \tag{3}$$

At the late-time residual level, G1 also gives the projection-locked branch

$$\mu(a,k) \simeq 1, \tag{4}$$

$$\Sigma(a,k) - 1 = -\frac{3}{4}(3-s)R_{bH}(a), \tag{5}$$

$$R_{bH}(1) = 1. \tag{6}$$

X3 does not depend on that empirical branch being finally confirmed. It uses the more basic G1 architecture: gravity is the global causal-screen ledger geometry row of the four-operation closure.

Central thesis

The operation basis is

$$\mathcal{O}_{\rm FDS} = \{\mathcal{O}_{\rm enc}, \mathcal{O}_{\rm conn}, \mathcal{O}_{\rm id}, \mathcal{O}_{\rm geom}\}, \tag{7}$$

where $\mathcal{O}_{\rm enc}$ is token encapsulation, $\mathcal{O}_{\rm conn}$ is connection and remote detectability, $\mathcal{O}_{\rm id}$ is identity-sector update, and $\mathcal{O}_{\rm geom}$ is global causal-screen ledger geometry.

In the observed physical world, the primary realizations are:

Interaction	Primary X3 operation role
Strong	hadronic/baryonic encapsulation of stable tokens
Electromagnetic	connection, composition, sensing, radiation
Weak	identity-sector conversion, decay, selective update
Gravity	causal-screen ledger geometry and stress-energy accounting

The map is primary-role, not exclusive-role. Real interactions can participate in many processes. X3 classifies each known interaction by the operation class it carries in a way the others do not generically replace.

FINITE PHYSICAL DISTINCTIONS AND OPERATION CLOSURE

Physical distinction maintenance

An active finite distinction system may be written schematically as

$$\mathcal{S} = (X, E, B, M, Y, A, U, \pi, \ell, \Phi, \mathcal{P}, \tau), \tag{8}$$

where X is internal state, E environment, B boundary, M memory/model state, Y observation channel, A action space, U update rule, π finite projection, ℓ boundary-maintenance loss, Φ resource budget, $\mathcal{P}$ perturbation/pruning family, and τ update timescale [1].

A physical distinction must do more than exist as a label. It must be:

1. stabilized as a persistent token;
2. connected to other tokens and observation channels;
3. transformable when its identity sector changes;
4. embedded in a global causal and resource-accounting structure.

These four requirements motivate Eq. (7).

Definition 1 (Operation closure)**.** *A physical operation set is closed for finite distinction maintenance when it provides mechanisms for token stabilization, connection or remote detectability, identity-sector update, and global causal-ledger accounting.*

Definition 2 (Primary operation role)**.** *A fundamental interaction has primary role $\mathcal{O}_i$ when it supplies the dominant observed carrier of a necessary operation class that the other known interactions do not generically implement without changing their own definitions or expanding the accounting boundary.*

Remark 1 (No-force-exclusion caveat)**.** *X3 does not say there can be only four particles, mediators, sectors, portals, or effective interactions. It says that new fundamental interactions should be classified by whether they instantiate one of the four operation classes or require a fifth operation primitive.*

A minimal coverage model

For auditability, define a requirement vector

$$\mathbf{r} = (r_{\rm enc}, r_{\rm conn}, r_{\rm id}, r_{\rm geom})^T \tag{9}$$

and a nonnegative coverage matrix C_{ij}, where row i indexes requirements and column j indexes operation carriers. In the ideal normal form,

$$C_0 = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}. \tag{10}$$

Real interactions have off-diagonal participation, so one should write

$$C = C_0 + \varepsilon C_{\rm cross}, \qquad 0 \le \varepsilon \ll 1, \tag{11}$$

where $C_{\rm cross}$ represents secondary roles. Closure requires full coverage rank and small residual deficit after requiring all four functions:

$$\operatorname{rank}(C) = 4, \qquad \Delta(C; \mathbf{r}) = \left\| [\mathbf{r} - C\mathbf{1}]_+ \right\|. \tag{12}$$

Removing operation j means deleting column j and recomputing Δ. A genuine operation primitive is one whose deletion leaves a nonzero functional deficit not removed by relabeling the other columns.

Criterion 1 (Operation-primitive audit)**.** *A proposed new force expands X3 only if its coverage vector has an irreducible component outside the span of the four existing operation classes under the chosen physical accounting boundary. Otherwise it is a sector extension, mixture, or new carrier of an existing operation class.*

VISUAL NORMAL-FORM OVERVIEW

This section imports the pedagogical layer from the earlier X3 manuscript into the operation-closure framing. The figures are deterministic normal-form diagrams. They are not empirical fits, not coupling-constant estimates, and not simulations of QCD, QED, electroweak theory, GR, or G1 cosmology.

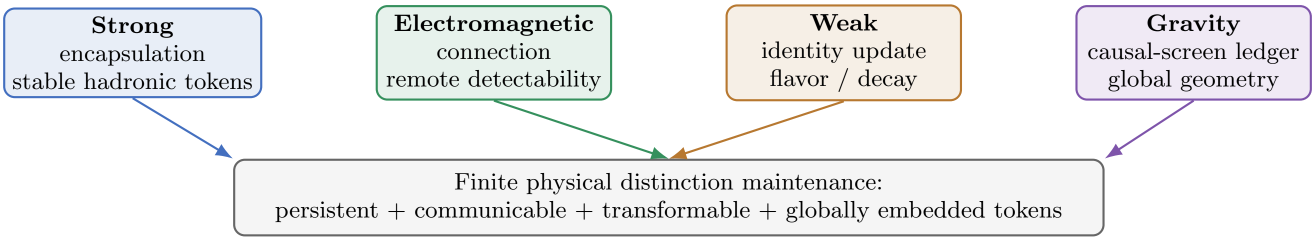

FIG. 1. Four known interactions as operation classes. The map is primary-role rather than exclusive-role: interactions cross-participate in real processes, but each supplies one operation primitive not generically replaced by the others.

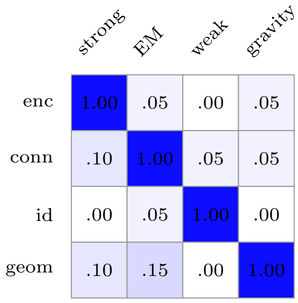

FIG. 2. Qualitative coverage matrix. Entries are schematic normal-form scores, not coupling constants or fitted quantities. Diagonal dominance records primary-role coverage; small off-diagonal entries record secondary participation.

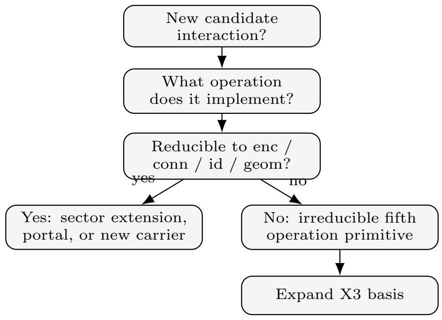

FIG. 4. Fifth-force audit tree. New particles or portals do not automatically refute X3. The closure basis is challenged only by a fundamental interaction implementing a necessary operation primitive outside the four-operation span.

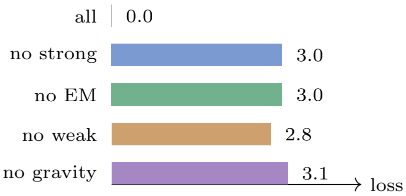

FIG. 3. Remove-one residual loss. Deleting each operation primitive leaves a distinct deficit: no stable tokens, no connection, no identity update, or no global causal ledger. Values are illustrative outputs of the normal-form audit. The absolute loss values carry no physical magnitude; only the nonzero pattern under remove-one deletion is used.

OPERATION I: STRONG INTERACTION AS ENCAPSULATION

Functional need

Finite physical distinctions require stable material tokens. Without token stabilization, there is no persistent substrate for memory, addressability, composite structure, or durable records. Encapsulation means binding raw degrees of freedom into protected tokens.

Observed implementation

The strong interaction realizes the bottom hadronic/baryonic token-stabilization layer through color confinement, color-neutral hadron formation, and nuclear binding. QCD is not replaced by FDS; X3 interprets confinement and color-neutral binding as the observed implementation of hadronic token encapsulation [9, 14–16].

This claim is deliberately narrow. Atomic, molecular, and condensed-matter stability require electromagnetism and quantum statistics. X3 assigns the strong interaction the primary role of stabilizing the lowest hadronic/baryonic material-token layer on which ordinary matter is built.

Gauge-group caveat

The observed implementation is $SU(3)_c$. X3 does not uniquely derive $SU(3)$ rather than another confining group. If another confining gauge theory realized the same encapsulation role in a different world, the gauge-specific mapping would be demoted while the operation role would remain.

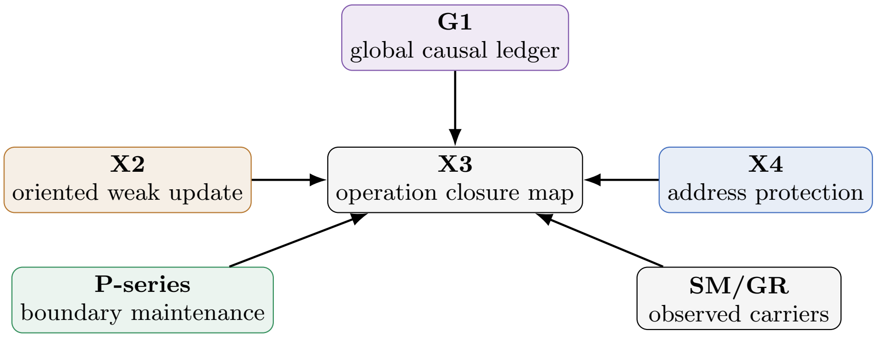

FIG. 5. Relation map. X3 is the operation-closure map inside the FDS physics spine. G1 supplies the gravity/global-ledger row; X2 supplies the weak identity-update module; X4 supplies matter-address protection; P-series papers supply boundary-maintenance constraints.

Failure if absent

Without encapsulation, there are no stable hadrons, no stable nuclei, and no long-lived baryonic matter tokens. A world with connection and geometry but no encapsulated matter substrate lacks persistent material carriers of distinctions.

OPERATION II: ELECTROMAGNETISM AS CONNECTION

Functional need

Encapsulated tokens must become mutually detectable and composable. A universe of perfectly isolated tokens could store local labels but could not form atoms, molecules, sensors, radiation channels, or communication networks. Connection means making distinctions available to other distinctions.

Observed implementation

Electromagnetism realizes connection through long-range interactions among charged sectors, atomic and molecular binding, radiation, sensing, and photon-mediated communication. Electromagnetism is the dominant channel by which ordinary matter becomes chemically structured, optically detectable, measurable, and communicable at macroscopic scales [9, 17].

Long-range detectability

The unbroken $U(1)_{\mathrm{EM}}$ and the masslessness of the photon provide the observed long-range connection channel. X3 does not derive photon masslessness. It interprets unbroken electromagnetism as the observed channel by which finite distinctions remain remotely detectable across macroscopic scales.

Failure if absent

Without electromagnetism, there are no ordinary atoms, chemical bonds, photons, optical sensing, radio communication, or electrically mediated macroscopic organization. Encapsulation without connection yields inert protected tokens rather than complex interacting structures.

OPERATION III: WEAK INTERACTION AS IDENTITY UPDATE

Functional need

Finite physical systems cannot merely preserve and connect identities. They also require controlled transformation of identity sectors: decay of unstable configurations, flavor conversion, and selective update. In X3, identity update means particle-sector, flavor-sector, or decay-channel conversion, not arbitrary time evolution, scattering, excitation, or binding rearrangement.

Observed implementation

The weak interaction realizes identity update through beta decay, quark flavor change, neutrino interactions, chirality-sensitive charged currents, and CP/T-oriented weak-sector transformation. A representative quark identity update is

$$\mathcal{T}_{\mathrm{id}} : |d_j\rangle \mapsto \sum_i V_{ij} |u_i\rangle, \tag{13}$$

where V_{ij} is the CKM matrix [6, 18, 19].

Relation to X2

X2 supplies the weak-sector orientation module. The safe X2 claim is not that all irreversibility requires CP/T violation. It is narrower: if weak identity update requires an intrinsic, basis-independent microscopic orientation invariant inside a unitary flavor-mixing structure, then fewer than three generations cannot supply a nonzero rephasing-invariant CP/T orientation, while three generations are the minimal nontrivial rank [6, 18, 19].

Thus X2 supports the weak row of X3:

$$\text{identity update} \Rightarrow \text{oriented weak flavor channel} \Rightarrow N_{\text{gen}} \geq 3 \quad (14)$$

under its stated assumptions.

Selective weakness

If identity update were uncontrolled or too rapid relative to encapsulation and connection, stable structures would be destroyed. The empirical weakness and mass gap of weak interactions are consistent with the functional requirement that identity update be selective rather than universal. This is a consistency interpretation, not a derivation of M_W, M_Z, the Fermi constant, or Yukawa textures.

Failure if absent

Without weak identity update, there is no beta decay, no observed quark flavor transition, no ordinary weak nuclear reaction chain as observed in stars, and no CP/T-oriented weak identity channel. Tokens could be stable and connected, but identity sectors would lack the observed selective transformation mechanism.

OPERATION IV: GRAVITY AS CAUSAL-SCREEN LEDGER GEOMETRY

Functional need

Finite physical distinctions are not isolated labels floating outside spacetime. They are embedded in causal structure, resource accounting, boundary conditions, horizons, and global consistency constraints. A physical world requires an operation class that ties local processes into a common causal and stress-energy ledger.

G1-strengthened realization

Gravity realizes this operation class through causal cones, horizons, curvature sourced by stress-energy, and universal coupling to energy-momentum [20–23]. G1 strengthens the FDS interpretation: gravity is finite causal-screen entropy-response geometry. The finite screen entropy ledger

$$S_{\text{scr}} : X_{\text{phys}} \to \mathbb{R} \quad (15)$$

provides the primitive accounting object; the response one-form gives local stiffness; all-null response data supply a metric envelope up to trace; and Ward/Bianchi closure enforces conservation of the physical response sector [8].

At the residual level, G1 also gives a late-time background–Weyl branch

$$\mu(a, k) \simeq 1, \quad (16)$$

$$\Sigma(a, k) - 1 = -\frac{3}{4}(3 - s) R_{bH}(a), \quad (17)$$

$$R_{bH}(1) = 1, \quad (18)$$

where $R_{bH}(a)$ is the normalized horizon-response output shape. X3 does not rely on this empirical branch being confirmed. It uses the more basic G1 architecture: gravity is the global causal-ledger and screen-response geometry row of the four-operation closure.

Gravity is not merely dissipation

X3 does not identify gravity with dissipation. Dissipation and resource accounting may appear inside gravitational boundary dynamics, but gravity is the independent geometric sector governing causal structure, horizons, and stress-energy consistency. Landauer-type cost provides a thermodynamic reference for physical erasure and reset operations, but gravity itself is not reduced to heat production [30].

Failure if absent

Without gravity there is no dynamical causal geometry, no universal stress-energy accounting, no horizon-scale boundary structure, and no global constraint tying local operations into one physical world.

MINIMAL OPERATION-CLOSURE PROPOSITION

Joint sufficiency and individual necessity

The four classes jointly provide token persistence, communicable relations, identity update, and global causal-ledger geometry. Remove one class and a distinct deficit appears:

Removed operation	Functional deficit
Encapsulation	no stable material tokens
Connection	no remote detectability, chemistry, or communication
Identity update	no flavor conversion, decay, or pruning channel
Causal ledger geometry	no common causal boundary / stress-energy accounting

Proposition 1 (Minimal physical distinction-operation closure)**.** *Consider a physical world supporting finite distinctions that are persistent, communicable, transformable, and globally embedded in causal/resource constraints. If operation classes are distinguished by irreducible function under a fixed accounting boundary, then at least four non-equivalent classes are required: encapsulation, connection, identity update, and causal-ledger geometry. In the observed world, the strong, electromagnetic, weak, and gravitational interactions realize these classes as primary roles.*

Proof. Persistence requires an operation that protects material tokens against dissolution into unaddressable degrees of freedom; this is encapsulation. Communication and composition require a mediating operation through which tokens become mutually detectable; this is connection. Decay, flavor change, and particle-sector conversion require a controlled transformation operation; this is identity update. Consistency of local processes inside a shared causal and stress-energy-constrained world requires a global boundary and geometry operation; this is causal-ledger geometry. By construction and by the independence criterion, omitting any one class leaves one requirement under-implemented by the remaining classes without redefining them or expanding the boundary. The proposition establishes a functional closure, not a unique gauge-dynamics derivation. □

FIFTH-FORCE AND NEW-PHYSICS AUDIT

New particle versus new operation primitive

X3 does not rule out new particles, portals, dark sectors, hidden gauge groups, axion-like particles, dark photons, scalar mediators, spin-dependent long-range interactions, or precision fifth-force deviations [27–29]. It only says that such candidates should be classified by operation primitive.

A candidate F_5 has an operation vector

$$\mathbf{v}_5 = (v_{\rm enc}, v_{\rm conn}, v_{\rm id}, v_{\rm geom}). \tag{19}$$

If $\mathbf{v}_5$ lies in the span or convex cone of the four existing operation columns, it is a new sector, mediator, or carrier of an existing operation class. If it contains an irreducible component orthogonal to the existing basis under the chosen accounting metric, then X3 must expand:

$$\mathcal{O}_{\rm FDS} \to \mathcal{O}_{\rm FDS} \cup \{\mathcal{O}_5\}. \tag{20}$$

This protocol is not a substitute for empirical force searches. It is a classification test after a candidate is specified.

Audit protocol

Protocol 1 (Fifth-operation audit)**.** *Given a proposed new interaction, ask:*

1. *Does it primarily stabilize material tokens?*
2. *Does it primarily create connection, sensing, or remote detectability?*
3. *Does it primarily update identity sectors, flavors, decay channels, or particle identity?*
4. *Does it primarily implement global causal-ledger geometry or stress-energy accounting?*
5. *If none apply, what necessary finite-distinction operation does it implement that the four classes cannot realize?*

Only a positive answer to the last question expands X3.

GAUGE-GROUP DISCUSSION: LOWER-STATUS MAPPING

The observed structures map to operation classes as follows:

Operation	Observed implementation
Encapsulation	$SU(3)_c$ QCD
Connection	unbroken $U(1)_{\rm EM}$
Identity update	weak charged-current / broken electroweak sector
Causal ledger geometry	diffeomorphism invariance / GR / G1 screen response

This table is a mapping, not a derivation. X3 does not uniquely derive $SU(3)$, $SU(2)$, $U(1)$, diffeomorphism invariance, electroweak symmetry breaking, or quantized gravity.

Remark 2 (Gauge-specific demotion)**.** *If another group structure realizes the same operation role in a consistent physical theory, the gauge-specific claim should be demoted while the functional operation role may survive.*

Higgs mechanism as implementation layer

The Higgs mechanism is not treated as a fifth operation class. It parametrizes mass generation and electroweak symmetry breaking inside the implementation of encapsulation, identity update, and long-range connection [9, 24–26]. In FDS language, masses may be interpreted as energetic separation scales between distinction sectors, but X3 does not derive the Higgs potential, vacuum expectation value, or Yukawa texture.

TABLE II. Normal-form interpretation of operation subsets. Values are schematic audit outputs, not empirical measurements.

Subset	Expected deficit	X3 interpretation
All four	none	closed basis
No strong	token stability	no encapsulation
No EM	detectability / composition	no connection
No weak	sector conversion	no identity update
No gravity	global ledger	no causal geometry
Add redundant fifth	none improved	carrier, not primitive

NORMAL-FORM MODEL

Purpose

The accompanying normal-form model is a deterministic audit model, not a physics simulation. It encodes the operation basis, checks remove-one deficits, and classifies candidate fifth forces by operation vector. It does not simulate QCD, QED, weak interactions, general relativity, or G1DE cosmology.

Coverage matrix and closure loss

A representative coverage matrix is

$$C = \begin{pmatrix} 1.00 & 0.05 & 0.00 & 0.05 \\ 0.10 & 1.00 & 0.05 & 0.05 \\ 0.00 & 0.05 & 1.00 & 0.00 \\ 0.10 & 0.15 & 0.00 & 1.00 \end{pmatrix}, \tag{21}$$

where rows are requirements $(\mathrm{enc}, \mathrm{conn}, \mathrm{id}, \mathrm{geom})$ and columns are the primary carriers $(\mathrm{strong}, \mathrm{EM}, \mathrm{weak}, \mathrm{gravity})$. The off-diagonal entries encode secondary participation. They are not coupling constants and are not fitted to data.

For a threshold vector $\mathbf{r} = (1, 1, 1, 1)^T$, closure loss for an operation subset S can be measured by

$$\Delta_S = \left\| \left[\mathbf{r} - \max_{j \in S} C_{\cdot j} \right]_+ \right\|_2 . \tag{22}$$

The full set has small or zero loss after normalization; remove-one subsets have distinct residual deficits. A redundant fifth mediator whose coverage vector lies in the convex span of the four columns does not remove a new deficit.

RELATION TO G1, X2, X4, AND NEARBY FDS MODULES

G1 supplies the gravity row

G1 is the technical development of the global causal-screen ledger row. It provides the finite screen entropy primitive, response geometry, Ward/Bianchi closure, Weyl-normalized residuals, and late-time residual interface [8]. X3 uses this to strengthen gravity from a loose "global accounting" label into a structured finite-screen response channel.

X2 supplies the weak identity-update module

X2 is the weak-sector module. It argues that an intrinsically oriented weak identity-update channel requires at least three generations under stated CKM-like assumptions [6, 18, 19]. X3 does not need the strongest version of X2. It needs only the weak row: observed weak interactions implement flavor and identity-sector transformation.

X4 supplies matter-address protection

X4 interprets Pauli exclusion as finite address protection. Given fermionic antisymmetry, same-address duplicate fermionic tokens have zero admissible amplitude. This is the matter-token counterpart of G1's causal-screen ledger: finite ledgers require protected addresses, and fermionic matter implements one address-protection rule [7].

P-series background

The P-series papers supply general finite-distinction constraints: finite-bath memory and Markovianization, anti-recurrence and hysteresis, speed-precision-dissipation bounds, and topological obstructions to forgetting [2–5]. X3 uses these as boundary-maintenance background, not as replacements for the physical interaction theories.

Relation table

FALSIFICATION AND DEMOTION CONDITIONS

X3 is weakened if stable physical tokens exist without any encapsulation/protection operation; if complex structure and observation exist without connection/detectability; if identity-sector transitions exist without transformation/update; or if global causal geometry and stress-energy accounting are irrelevant to physical distinction maintenance.

X3 is falsified or expanded if a fundamental interaction is found that implements a necessary operation class not reducible to encapsulation, connection, identity update, or causal-ledger geometry. Gauge-specific claims

TABLE III. Relation of X3 to nearby FDS papers and established theories.

Theory / paper	What it provides	X3 use
QCD	Confinement, color dynamics, hadrons, nuclear matter	Observed implementation of hadronic/baryonic encapsulation.
QED / electromagnetism	Long-range photon-mediated interaction, atoms, radiation, sensing	Observed implementation of connection and remote detectability.
Electroweak theory	Chiral weak currents, beta decay, flavor change, EWSB	Observed implementation of identity update.
General relativity	Causal geometry, curvature, horizons, stress-energy accounting	Observed implementation of global boundary and geometry.
G1	Finite causal-screen entropy response, Ward closure, Weyl-normalized residuals	Technical strengthening of the gravity row, not a dependency on any particular G1DE evidence result.
X2	Minimal CP/T-oriented weak identity-update rank	Weak-interaction module inside the taxonomy.
X4	Pauli exclusion as finite address protection	Matter-token address protection supporting encapsulated distinction stability.
P-series	Boundary maintenance, finite memory, dissipation, hysteresis, obstruction to forgetting	General finite-distinction background constraints.
Fifth-force searches	New particles, portals, deviations, hidden-sector mediators	Classification test: new carrier or new operation primitive?

are lower-status: if alternative group structures realize the same operation roles, the gauge mapping should be demoted rather than the closure thesis.

CONCLUSION

X3 proposes that the four known interactions occupy four non-equivalent operation roles required by finite physical distinction systems. Strong interaction stabilizes hadronic/baryonic material tokens; electromagnetism connects and exposes distinctions to remote detection; weak interaction transforms identity sectors and enables selective flavor/particle-sector update; gravity supplies global causal-screen ledger geometry and stress-energy accounting. The G1 program strengthens the gravity row by providing a finite-screen entropy-response architecture. X2 strengthens the weak row by isolating the minimal rank needed for a CP/T-oriented identity-update invariant. X4 strengthens the matter-token side by interpreting Pauli exclusion as finite address protection.

This is not a derivation of the Standard Model and not a denial of possible new physics. It is a closure claim: persistent physical distinctions require encapsulation, connection, identity update, and global causal-ledger geometry, and the known interactions realize those four operation classes in our universe.

Machine-readable normal-form model

The accompanying Python model implements the following minimal audit:

1. define the operation basis $(\mathcal{O}_{\rm enc}, \mathcal{O}_{\rm conn}, \mathcal{O}_{\rm id}, \mathcal{O}_{\rm geom})$;
2. define a qualitative coverage matrix C;
3. compute remove-one closure losses;
4. classify candidate fifth forces by projection onto the existing operation span;
5. emit a JSON report with model assumptions and outputs.

The code is a reference normal-form model only. It is not a simulation of the Standard Model or gravity.

Claim hierarchy

The strongest claim in X3 is the operation-closure thesis. The weaker claims are gauge-specific mappings and optional interpretations of why particular implementations have their observed quantitative parameters. This hierarchy should be preserved in any future revision:

1. **Operation closure:** four necessary operation classes; this is the core X3 thesis.
2. **Observed mapping:** the known interactions realize those classes; this is a physical bridge.
3. **Gauge specifics:** $SU(3)$, $U(1)$, electroweak structure, and diffeomorphism invariance are lower-status implementation mappings.

4. **Parameter derivation:** masses, couplings, mixings, and amplitudes are not claimed.

Appendix-style note: Design implication for physical AI

This section is not part of the physics proof. It extracts the FDS design rule implied by X3. A boundary-maintaining agent requires analogues of the same four functions: protected tokens, communication links, identity revision, and global resource/safety-envelope accounting.

Missing operation class	Agent failure mode
Encapsulation	identity drift / unstable object tokens
Connection	isolated modules / broken relation graph
Identity update	stale state / dead logic / overfitting
Global boundary	resource overshoot / unsafe action

The lesson is not that AI systems need copies of physical forces. It is that stable boundary maintenance requires an operation closure analogous to the physical one.

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