

WIS / TOE • INFORMATION ARCHITECTURE SERIES

PARTICLE INFORMATION ARCHITECTURE

From fundamental particles to spacetime programming

A 3+1D systems-science map of the Standard Model inventory, particle-state registers, interaction opcodes, and the proposed graviton extension

THE SEPARATION RULE

Physical particle properties and interactions are reported as established physics. Computational labels such as COMPOSE, TRANSFER, and GEOMETRIZE are exploratory WIS/TOE interpretations. The five-state graviton qdit is a model hypothesis, not an established property of the massless graviton.

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AUTHOR'S NOTE

Scope, status, and reading guide

This manuscript turns the existing Particle Information Architecture (PIA) reference into an editable research document and aligns it with the current 3+1D direction of the Theory of Everything (TOE), All Is Epistemic. The aim is not to replace quantum field theory with computer language. It is to build a disciplined systems representation of particle identity, state structure, interaction, composition, measurement, and—more speculatively—geometry.

The document separates three kinds of statement. Established physics describes the Standard Model fields and the experimentally constrained behavior of their excitations. Mathematical representation defines registers, state spaces, operators, and legal transformations. The TOE/PIA interpretation proposes that this vocabulary may illuminate physical organization and, in the graviton case, motivate a research program for spacetime computing. These categories must not be collapsed.

What changed in this edition

- The arena is explicitly 3+1D spacetime. No extra spatial dimensions, compact dimensions, or dimensional-counting assumptions are required by the PIA register architecture.
- Internal state-space dimension is kept separate from spacetime dimension: a five-dimensional computational register does not mean five spatial dimensions.
- The graviton qdit is described as a proposed five-state computational register associated with a gravitational sector. The ordinary massless spin-2 radiative sector in 3+1D has two physical helicities.
- Particle-data values are rounded reference values rather than immutable constants; quark-mass definitions, neutrino mass constraints, and experimental averages require the conventions of the cited PDG edition.
- The opcode vocabulary is marked as a modeling language. An opcode becomes a physical claim only when tied to specified dynamics and observables.

OPERATING CONTRACT

The particle inventory is the baseline. The computational mapping is a proposal. Every proposed physical extension must recover known results, state its assumptions, and expose itself to quantitative failure.

ABSTRACT

Abstract

Particle Information Architecture (PIA) is a systems-science framework for representing known particle fields and their interactions as structured information states and constrained transformations. The physical starting point is conventional: in quantum field theory, particles are excitations of fields; their spin, charges, masses, gauge representations, and interaction channels are not invented by the information model. PIA encodes relevant properties into a composite register, then assigns a provisional systems opcode—such as COMPOSE, TRANSFER, CORRELATE, or PROPAGATE—to the role a state or interaction plays in a model.

The architecture distinguishes physical identity, relational structure, and computational interpretation. It treats quark color as an internal gauge representation, not visual color; separates neutrino flavor from mass eigenstates; distinguishes physical polarization counts from larger representation spaces; and treats particle-antiparticle relations as transformations of the complete physically relevant register. Conservation laws, gauge structure, statistics, kinematics, and dynamical amplitudes define the legal transition space.

The gravitational extension is deliberately more conjectural. The document explores a five-state computational register associated with the gravitational sector and assigns the hypothesis the opcode GEOMETRIZE: a candidate operation that would change the relational geometry in which other state transformations occur. This register is not asserted to be five observed polarizations of a massless graviton. A successful model must define a Lorentz-consistent 3+1D map to gravitational observables, recover the tested low-energy limit of General Relativity—including its two radiative modes—and produce a distinguishable quantitative prediction.

PIA is therefore a translation layer and a falsifiable research program, not evidence that the universe literally runs conventional software. Its value depends on whether the architecture clarifies constraints, improves simulation, or yields predictions beyond a relabeling of standard theory. The governing maxim remains: reality wins.

Executive summary

Layer	Physical / mathematical object	PIA interpretation	Status
I. State	Field excitation with quantum numbers	Differentiate / identify	Established baseline + representational choice
II. Relation	Interaction, coupling, joint state	Relate / transform / correlate	Physics established; opcode names are interpretive
III. Composition	Bound or composite system	Compose under symmetry and statistics	Established physics + system-level abstraction
IV. Geometry	Metric, causal structure, curvature	Organize relations; candidate GEOMETRIZE operation	General Relativity established in tested regime; deeper map conjectural
V. Measurement	Outcome distribution and record	Measure; estimate; revise model	Measurement theory established; interpretation varies
VI. TOE extension	Five-state register associated with gravity	Candidate spacetime-computing primitive	Hypothesis requiring a physical derivation

K3: THE OPERATIONAL KERNEL

DIFFERENTIATE → RELATE → MEASURE. In PIA, K3 is a compact modeling grammar. Its stronger TOE interpretation—that this grammar is built into physical reality—is a philosophical/physical hypothesis, not a result proved by the particle inventory.

01 / THE PREMISE

From particles to computation

The physical inventory comes first. The computational interpretation comes second. Standard Model physics already gives us a highly structured set of fields, quantum numbers, symmetries, and interaction rules. PIA asks a systems question: can we encode this structure in a representation that makes identity, relation, state change, and composition easier to reason about, simulate, and test?

Three layers of meaning

Layer	Question	PIA object
Physical	What is the excitation and which field does it belong to?	Field excitation, particle species, quantum numbers
Relational	What states can it couple to, and under which rules?	State space, interaction channel, symmetry constraints
Computational	What formal operation captures the role of this relationship in a model?	Qubit/qudit register, state map, system opcode

What PIA does—and does not—mean

- A “register” is a structured representation of a physical sector. It need not imply a tiny classical computer hidden inside a particle.
- A “bit” label is shorthand for a two-state distinction; a qubit is a two-dimensional quantum state space; a qudit has dimension d . None of these labels alone establishes how much classical information can be extracted.
- An “opcode” names a role in a model. It is not automatically a new elementary interaction or a Standard Model operator.
- A lawful transition must be generated by a physical interaction or a defined quantum channel and must respect the applicable constraints. A pleasing computational analogy cannot make a forbidden transition happen.

The research test

The translation is worthwhile only if it does more than rename familiar quantities. It should make state-space structure explicit, preserve the legal transition set, support reproducible computation, or reveal a compact relation that conventional notation obscures. If it does none of these, the simplest conclusion is that the added architecture has not earned its keep.

REALITY VETO

Elegance is not evidence. No particle label, opcode, or TOE conjecture is exempt from correction when data or a mathematical inconsistency says otherwise.

02 / THE CORE MODEL

The particle register

A particle or field-excitation record is represented schematically as a composite register:

PIA PARTICLE RECORD

$P = [F, S, M, Q, R, G, \Lambda, D; \xi]$

Symbol	Meaning	Modeling caution
F	Field / family identity	A species label belongs to a specified field theory.
S	Spin, helicity, or relevant angular-momentum structure	Physical degrees of freedom depend on mass, gauge symmetry, and constraints.
M	Mass information or mass parameter	For quarks and unstable particles, the mass convention and extraction method matter.
Q	Additive quantum numbers and charges	Only the relevant conserved or approximately conserved quantities should be included.
R	Gauge / internal representation	Examples include SU(3) color representation; not an ordinary spatial address.
G	Generation or flavor information	Flavor labels need not coincide with propagation or mass eigenstates.
Λ	Additional theory-specific labels	Keep only labels required by the relevant model.
D	Selected internal state-space degrees of freedom	A finite register is a projection of the full physical state only where justified.
ξ	Kinematic or contextual variables, when needed	Momentum, wave-packet data, position, and environmental context may be continuous or field-theoretic.

The register is not a claim of simultaneous sharp values

The notation is an architecture for bookkeeping and computation, not an assertion that every particle carries a complete classical list of simultaneously definite attributes. Quantum states can be superposed; some observables do not commute; field excitations are represented in a theory-specific basis; and interactions can entangle subsystems. The register must preserve exactly the distinctions needed for the calculation without pretending that representation labels are all jointly measurable.

State and evolution

For a finite-dimensional subspace, a normalized pure state can be written $|\psi\rangle = \sum_i a_i |i\rangle$ with $\sum_i |a_i|^2 = 1$. A closed-system quantum evolution has the form $|\psi\rangle \rightarrow U|\psi\rangle$, with $U^\dagger U = I$. For a subsystem interacting with an environment, a density operator ρ or a completely positive trace-preserving map may be required. These are standard mathematical structures; the PIA question is how they map to the chosen particle sector.

KEEP THE BOUNDARIES CLEAN

A Hilbert-space dimension counts basis directions in the selected mathematical state space. It is not a count of spatial dimensions, nor automatically a count of experimentally distinguishable particle polarizations.

03 / THE PHYSICAL BASELINE

Master ledger: the particle inventory

The following ledger is a compact architectural map, not a substitute for the Particle Data Group (PDG) tables. Values are rounded for orientation. Quark masses depend on the stated mass scheme and scale; neutrino absolute masses are not individually resolved by the flavor labels; and the graviton remains hypothetical.

Particle / sector	Class	Spin	Relevant state structure	Representative mass / status	PIA opcode
u, d, c, s, t, b	Quarks	1/2	SU(3) color triplet; spin subspace	Scheme-dependent; from a few MeV (u,d) to ~173 GeV (t)	COMPOSE
e, μ , τ	Charged leptons	1/2	Spin states; electric charge -1	0.511 MeV; 105.66 MeV; 1.777 GeV	IDENTIFY
ν_e , ν_μ , ν_τ	Neutrinos	1/2	Flavor and mass bases related by mixing	Nonzero mass-squared differences; absolute masses bounded	PROPAGATE
γ	Photon	1	Two physical helicities in the massless theory	Consistent with massless in the Standard Model	TRANSFER
g	Gluon	1	SU(3) adjoint (8 color components); transverse polarizations in perturbative QCD	Massless gauge field in the Standard Model description	CONNECT
W^+ , W^-	Weak gauge bosons	1	Massive spin-1; 3 physical polarization states	~80.4 GeV	TRANSFORM
Z^0	Weak gauge boson	1	Massive spin-1; 3 physical polarization states	~91.2 GeV	CORRELATE
H	Higgs boson	0	Scalar excitation	~125.2 GeV	PARAMETERIZE
G (graviton)	Hypothetical spin-2 gravitational quantum	2 (hypothesis)	Two massless radiative helicities in the standard 3+1D limit; a separate five-state register is proposed computationally	Not detected as an individual particle	GEOMETRIZE*

Status key: established means included in the Standard Model or supported by extensive evidence; “hypothetical” means not experimentally established as an individual particle; “PIA opcode” is a systems-level analogy rather than a standardized physical label.

Why the ledger does not flatten everything into one number

An inventory is helpful only when it preserves factorization. A quark’s spin state and its color representation are not the same degree of freedom. A gluon’s adjoint color structure is not the same thing as its physical polarization. Neutrino flavor is not a mass eigenstate. And a five-dimensional computational register cannot be counted as five physical polarizations unless a physical theory derives that identification.

04 / MATTER PRIMITIVES

Quarks: compositional primitives

Quarks are spin-1/2 fermionic fields with six flavors—up, down, charm, strange, top, and bottom—and an SU(3) color degree of freedom. They are not observed as isolated free particles under ordinary conditions; quantum chromodynamics confines them into color-neutral hadrons. This makes them natural examples for a system architecture concerned with composition under strong relational constraints.

Symbol	Flavor	Electric charge	Representative mass scale	PIA representation	Opcode
u	up	+2/3	~2 MeV	spin-1/2 × color triplet	COMPOSE
d	down	−1/3	~5 MeV	spin-1/2 × color triplet	COMPOSE
c	charm	+2/3	~1.27 GeV	spin-1/2 × color triplet	COMPOSE
s	strange	−1/3	~0.09 GeV	spin-1/2 × color triplet	COMPOSE
t	top	+2/3	~173 GeV	spin-1/2 × color triplet	COMPOSE
b	bottom	−1/3	~4.2 GeV	spin-1/2 × color triplet	COMPOSE

Mass values above are rounded orientation values. Light-quark masses are quoted in a renormalization scheme and at a scale; heavy-quark mass definitions also differ by scheme. Consult the current PDG quark-mass review for formal use. [1, 4]

The computational reading

- COMPOSE means preserve distinguishable constituents while deriving higher-order states from their allowed joint relationships.
- Color is an internal gauge degree of freedom, not a visible hue and not a literal network address. The register should encode the appropriate SU(3) representation and gauge constraints.
- The same flavor family uses a recurring spin/color architecture at widely different mass and coupling scales. PIA can record that repeated structure without claiming that the flavor hierarchy has been explained.

Why not call it one six-state qudit?

For a selected single-quark spin × color basis, $2 \times 3 = 6$ basis states can be represented in a six-dimensional product space. But retaining the factorization is often more useful than calling it a single indivisible six-state object: spin and color transform differently and obey different physical rules. More generally, the smallest representation that preserves the relevant operation is the right one—not the smallest label that looks elegant.

PHYSICAL CONSTRAINT

A register that models quarks must respect color gauge structure, fermionic statistics, and the confinement dynamics relevant to the process. “Compose” cannot mean arbitrary concatenation.

05 / MATTER PRIMITIVES

Leptons: identity and propagation

Charged leptons and neutrinos illustrate why a register should represent the physical role and the measurement basis separately. Electron, muon, and tau are charged spin-1/2 leptons. Neutrinos are also spin-1/2 fermions, but flavor and mass states are related by mixing, so a single flavor label is not a complete propagation description.

Particle	Charge	Representative mass / constraint	Physical behavior	PIA role
electron (e)	-1	0.511 MeV	Stable under known interactions	IDENTIFY
muon (μ)	-1	105.66 MeV	Unstable; decays through weak interaction	IDENTIFY → TRANSFORM
tau (τ)	-1	1.777 GeV	Unstable; multiple decay channels	IDENTIFY → TRANSFORM
ν_e	0	Absolute mass unresolved	Flavor component; participates in oscillation	PROPAGATE / MIX
ν_μ	0	Absolute mass unresolved	Flavor component; participates in oscillation	PROPAGATE / MIX
ν_τ	0	Absolute mass unresolved	Flavor component; participates in oscillation	PROPAGATE / MIX

Neutrino flavor is not the mass basis

Neutrino oscillations demonstrate that flavor composition changes during propagation. In the standard three-flavor description, flavor states are coherent combinations of mass eigenstates. PIA should therefore store the chosen basis and mixing map explicitly rather than treating ν_e , ν_μ , and ν_τ as three independent mass values. The known mass-squared splittings establish that neutrinos are not all massless; direct measurements constrain, rather than individually resolve, their absolute masses. [1, 5]

The computational reading

- IDENTIFY: label a physically distinct field or state sector while retaining the quantum numbers relevant to later interaction.
- PROPAGATE: evolve a state through spacetime or an interaction channel; the model must specify the Hamiltonian, phases, mixing, and any environmental effects.
- MIX: update the relation between basis states under the relevant unitary evolution. This is a suggested auxiliary opcode, not a new interaction in particle physics.

ANTI-MISTAKE

An information “function” does not mean a particle has intention, agency, or a software instruction stored inside it. The function is the role a state or channel plays in the chosen systems model.

06 / INTERACTION PRIMITIVES

Gauge bosons and the Higgs sector

This is where the computational vocabulary can be especially practical: interaction terms in a theory specify which fields couple and how joint states evolve. PIA assigns concise names to those modeling roles, while the underlying interaction remains the one specified by the physical theory.

Excitation	Physical structure	Baseline role	PIA opcode	Systems reading
Photon (γ)	Massless spin-1; 2 physical helicities	Electromagnetic field coupling to electric charge	TRANSFER	Interaction / signaling channel
Gluon (g)	Massless spin-1; SU(3) adjoint with 8 components	Strong interaction; gluon self-interactions	CONNECT	Gauge-constrained relational network
$W^\pm$	Massive spin-1; 3 physical polarization states	Charged weak current; flavor-changing processes	TRANSFORM	Allowed state conversion
Z^0	Massive spin-1; 3 physical polarization states	Neutral weak current	CORRELATE	Neutral-current interaction and state relation
Higgs (H)	Spin-0 scalar excitation	Excitation of the Higgs field; couplings related to electroweak symmetry breaking	PARAMETERIZE*	Track coupling/scale roles in a model

The asterisk on PARAMETERIZE marks the systems label, not a claim that the Higgs boson literally sets global parameter values by executing an instruction. In the underlying physics, masses and couplings follow from the Lagrangian and the Higgs mechanism, not from a software opcode.

The interaction network

Interaction sector	Carriers / fields	Affected sectors	PIA interpretation
Electromagnetic	Photon and electromagnetic field	Charged quarks and leptons; other charged states	TRANSFER
Strong	Gluon field and QCD interactions	Quarks and gluons	CONNECT / CONSTRAIN
Weak	W and Z fields	Quarks and leptons with chiral structure	TRANSFORM / CORRELATE
Higgs / electroweak symmetry breaking	Higgs field and its couplings	Fields coupled to the Higgs sector	PARAMETERIZE*
Gravity	Metric/geometry; graviton only if a quantum description is established	Stress-energy and gravitational degrees of freedom	GEOMETRIZE*

The Standard Model describes electromagnetic, strong, and weak interactions and includes the Higgs sector. Gravity is not incorporated as a quantum interaction within the Standard Model itself; the graviton remains hypothetical. [2, 3]

07 / COMPUTATIONAL ONTOLOGY

What does “bit” mean here?

The vocabulary must be precise enough to prevent state-space notation from being mistaken for a claim about literal microscopic digital hardware.

Term	Mathematical meaning	PIA use	Common mistake to avoid
Bit	Two classical alternatives	Binary bookkeeping label	Assuming all physical distinctions are classical bits
Qubit	Two-dimensional quantum state space	Spin or helicity subspace when physically appropriate	Confusing dimension 2 with two simultaneously readable classical bits
Qutrit	Three-dimensional state space	Example: spin-projection space of a massive spin-1 particle	Calling every three-labeled quantity a qutrit regardless of constraints
Qudit	d-dimensional quantum state space	General register abstraction	Assuming d is a count of spatial dimensions or a count of independent physical polarizations
Composite register	Tensor product of subsystem spaces plus constraints	Factorized state model for spin, color, flavor, etc.	Ignoring symmetries, entanglement, statistics, or gauge constraints

Representation dimension versus physical polarization

A massive spin-s representation in its rest frame has $2s+1$ spin projections. Massless gauge fields are different because gauge structure and constraints leave only the physical helicity states: in the standard 3+1D description a photon has helicities ± 1 , and a massless spin-2 radiative field has helicities ± 2 . Massive spin-1 W and Z bosons have three physical polarization states. A conventional massive spin-2 representation has five physical polarizations. These statements refer to different representations and cannot be freely interchanged. [6, 7]

Why state dimension is useful

- It makes the basis explicit and helps specify a simulator or quantum circuit.
- It permits algebraic comparisons between candidate state encodings.
- It exposes over-counting: if a proposed register duplicates gauge, constraint, or polarization degrees of freedom, the redundancy should be identified.
- It does not prove a register physically exists. A mathematical representation may be useful without matching a fundamental object in nature.

THE MINIMUM-SUFFICIENT-STATE RULE

Choose the smallest state representation that preserves the distinctions needed for the target calculation. Do not enlarge a register merely because a larger number creates a more attractive analogy.

08 / THE HYPOTHETICAL EXTENSION

The graviton: geometry as information

Gravity is the architectural hinge. Ordinary PIA opcodes describe state evolution or relationships inside a specified dynamical framework. GEOMETRIZE is reserved for a stronger possibility: that gravitational degrees of freedom participate in updating the effective relational geometry itself. This is a TOE/PIA hypothesis, not an established Standard Model interaction opcode.

The 3+1D physical baseline

In General Relativity, spacetime geometry is represented by a metric and its curvature. In perturbative treatments, small fluctuations about a background can be represented by a spin-2 field. The graviton is the hypothetical quantum of the gravitational field in a quantum description; no individual graviton has been directly detected. In the standard massless 3+1D limit, the radiative sector has two physical helicities, +2 and -2. A conventional massive spin-2 representation has five physical polarizations, but that fact does not establish that the observed massless gravitational field is a five-state particle. [2, 6, 7]

Description	Count	Status and meaning
Massless spin-2 radiative sector in 3+1D	2 helicities	Standard physical baseline relevant to low-energy gravitational waves
Conventional massive spin-2 representation	5 polarizations	Established representation-theory count for a massive spin-2 field; any interacting model needs consistency and stability analysis
PIA / TOE gravitational register	5 computational basis states	Model hypothesis; its relation to physical gravitational degrees of freedom must be derived
Low-energy recovery map	2 radiative modes required	A proposed Q5 model must recover the two-mode massless sector where General Relativity is tested

The five-state register

For computational experiments, define an abstract five-level register $H_5 \cong \mathbb{C}^5$ with an orthonormal basis $\{|G_0\rangle, |G_1\rangle, |G_2\rangle, |G_3\rangle, |G_4\rangle\}$. A normalized state may be written $|\psi_G\rangle = \sum_{j=0}^4 a_j |G_j\rangle$, with $\sum_j |a_j|^2 = 1$. This is a mathematically well-defined qdit regardless of whether nature realizes it as a fundamental gravitational register.

The TOE conjecture is that the five-state architecture may encode a richer computational structure associated with gravity than the two radiative degrees of freedom visible in the massless, low-energy sector. A candidate map must specify how the register couples to the metric or another geometric observable, how symmetries and constraints are implemented, and which states survive as physical low-energy modes. Naming two states “classical spacetime” does not suffice; the projection must follow from a defined dynamical model.

DIMENSIONAL DISCIPLINE

The register dimension $d = 5$ is internal state-space structure. Spacetime remains 3+1D throughout this manuscript. No extra spatial dimensions are used to explain the five states.

09 / FROM REGISTER TO GEOMETRY

GEOMETRIZE: the spacetime-computing hypothesis

What would GEOMETRIZE do?

Operationally, GEOMETRIZE* would denote a proposed map from an underlying gravitational state or joint register to effective geometric data: a metric, a curvature observable, a causal relation, or a specified perturbation of one of these. The asterisk is mandatory until that map is derived. It reminds the reader that an opcode label is not yet a physical operator.

SCHEMATIC ONLY

Q5 state / joint gravitational state $\rightarrow$ derived map $\Phi \rightarrow$ effective geometric observable $\rightarrow$ detector-level prediction

The schematic becomes physics only when Φ is mathematically specified, its domain and codomain are clear, and a dynamical law determines how its output evolves. Ideally the relation is derived from an action, Hamiltonian, or controlled effective theory rather than chosen to fit a desired result after the fact.

The “Braille the manifold” analogy, translated carefully

The analogy is that local state changes may leave a pattern in relational geometry, in the way a structured surface makes a pattern readable by touch. The disciplined translation is not that spacetime literally contains writing or a conventional program. It is the hypothesis that microscopic gravitational states and interactions could determine the effective metric and causal structure reconstructed at larger scales.

Analogy term	Mathematical target	Required definition
Raised / recessed mark	Local state or field perturbation	State variable and physically meaningful basis
Pattern grammar	Couplings and allowed transitions	Action/Hamiltonian, symmetry, and constraints
Surface geometry	Metric / causal structure / curvature	Observable map from microstate to effective geometry
Reading the pattern	Measurement and inference	Detector response, outcome distribution, uncertainty
Writing a new pattern	A changed gravitational state or geometry	Derived interaction and a distinct measurable consequence

What must not be smuggled in

- No equation equating five computational states with five physical massless-graviton polarizations.
- No extra spatial dimensions to host the register, and no assumption that internal state labels are hidden geometric axes.
- No automatic inference from a rich qdit algebra to controllable spacetime manipulation.
- No identification of a dark-matter or dark-energy signal with hidden gravitational states until a unique model predicts the observations and competing explanations are excluded.

Minimum physics interface

1. Specify the covariant or otherwise well-justified 3+1D dynamical description and its degrees of freedom.
2. Define how the five-state register transforms under the relevant spacetime symmetries and constraints.
3. Derive the coupling to an observable geometric quantity; preserve stability, unitarity, and the applicable conservation relations.
4. Recover General Relativity and the two radiative massless spin-2 modes in the tested regime.
5. Produce at least one controlled prediction not already forced by the baseline theory.

10 / RELATIONAL IDENTITY

Antiparticles and conjugate registers

The PIA register supports a clean description of antiparticles as conjugate information states. This extends the central PIA vocabulary without requiring every particle to have a distinct antiparticle register or reducing conjugation to a sign flip of electric charge alone. The companion manuscript, Antiparticle Information Architecture, treats this topic in detail. [8]

CONJUGATION MAP

$\bar{P} = C(P)$ • $C^2 = I$ (within the relevant register convention)

Here C acts on the complete physically relevant state according to the conjugation rules of the underlying theory. Mass and spin magnitude are preserved for corresponding particle/antiparticle species; additive quantum numbers reverse where required; and internal gauge representations are conjugated. Other labels transform according to the specific particle sector and chosen formalism.

Case	Architecture	Example / implication
Distinct partner	$C(P) \neq P$	Electron / positron: separate particle and antiparticle states
Self-conjugate sector	$C(P) = P$ (appropriately defined)	Photon is the canonical Standard Model example; the full field representation matters
Pair creation	Initial state evolves into a permitted particle–antiparticle pair	Must satisfy energy, momentum, charge, angular momentum, and interaction constraints
Annihilation / recombination	Initial excitations disappear; permitted final excitations remain	Not “information becomes nothing”; conserved quantities are carried into final states

Antiparticle opcodes

Opcode	Operation represented	Constraint
C_INV	Apply the relevant conjugation map	Use the theory-specific transformation; do not confuse C with CP or CPT
Q_REV	Reverse applicable additive charges	Only quantities actually transformed by charge conjugation
REP_CONJ	Conjugate internal representation	Preserve the correct gauge-group structure
PAIR_CREATE	Represent allowed pair creation	Use physical amplitudes and kinematics
RECOMB	Represent pair annihilation into allowed final states	Respect conservation laws and interaction channels
FIX_C	Test the self-conjugate/fixed-point condition	Requires complete quantum numbers and field representation

ARCHITECTURAL PRINCIPLE

Particle identity is relational. The antiparticle is defined by a transformation of the complete relevant register—not by a single field being assigned the opposite electric charge.

PIIS: Particle Information Instruction Set

PIIS is a provisional grammar for making PIA operational in simulations and model descriptions. The syntax is not a claim that particle physics executes human-readable commands. It is a disciplined way to state what a program is representing and which constraints govern it.

Instruction frame

PROPOSED RECORD SYNTAX

[SOURCE] [OPCODE] [TARGET] [STATE] [CONSTRAINT]

Opcode	Formal role	Example abstract instruction	Status
RD / READ	Acquire model-accessible state data	RD field_q $\rightarrow$ register_q	Information-processing operation
ME / MEASURE	Apply a specified measurement and record outcomes	ME $\rho, \{E_i\} \rightarrow \{i, p_i\}$	Physical measurement model required
TR / TRANSFER	Represent a defined channel between sectors	TR state_A $\rightarrow$ state_B	Must follow a coupling / channel
CN / CONNECT	Represent a relation or interaction edge	CN A $\leftrightarrow$ B	Edge is meaningful only if grounded in dynamics
TF / TRANSFORM	Evolve a state under a defined map	TF $\rho \rightarrow \rho'$	Map must be specified
CR / CORRELATE	Compute joint-state correlations	CR $\rho_{AB} \rightarrow C_{AB}$	Must distinguish classical correlation from entanglement
ID / IDENTIFY	Attach a field/species label	ID state $\rightarrow$ species_f	Model bookkeeping; no new physics
CP / COMPOSE	Construct composite-state space	CP A $\otimes$ B $\rightarrow$ AB	Apply symmetries, statistics, and gauge constraints
PR / PROPAGATE	Evolve state through spacetime/channel	PR $\rho(t) \rightarrow \rho(t+\Delta t)$	Hamiltonian/channel needed
PA / PARAMETERIZE	Represent model parameters or couplings	PA $\theta \rightarrow \text{model}(\theta)$	Not a claim that a particle sets parameters by software
GE* / GEOMETRIZE	Candidate map from gravitational state to geometry	GE* $\psi G \rightarrow g_{\text{eff}}$	Conjectural physical interface
RV / REVISE	Update an external model against evidence	RV model, data $\rightarrow$ model'	Epistemic operation; not a particle interaction

The abbreviations are proposed design choices for PIIS, not established Standard Model nomenclature. Keep them versioned: meaning should not silently drift as the physical hypotheses evolve.

Legal transition constraints

- Conservation and selection rules applicable to the process, including energy-momentum and angular momentum where the physical setting defines them.
- Gauge invariance and the corresponding charge/representation constraints.
- Quantum statistics, including fermionic antisymmetrization or bosonic symmetrization when constructing composite states.
- Kinematic accessibility, interaction amplitudes, and the correct boundary/initial conditions.
- Causality, locality, covariance, and stress-energy consistency required by the chosen gravitational framework.

12 / OPERATIONAL SEMANTICS

An executable PIA cycle

A useful information architecture is one that can be executed without losing contact with physics. The following cycle is a minimal model sketch. It is not a new fundamental theory; it is a contract for what a PIA implementation must make explicit.

Step	Instruction	Input → output	Validation question
1	READ / ID	Selected field sector → labeled register	Are the species and basis labels unambiguous?
2	MEASURE	State and POVM / detector model → outcome distribution	Are probabilities normalized and detector assumptions explicit?
3	TRANSFORM / PROPAGATE	State and derived dynamics → evolved state	Is the map unitary or a valid quantum channel, as required?
4	CORRELATE	Joint state → correlation / entanglement diagnostics	Are basis dependence and environmental effects handled?
5	COMPOSE	Subsystem registers → composite state	Are gauge constraints and quantum statistics preserved?
6	GEOMETRIZE*	Gravitational register → geometric observable	Is this map derived, unique, and physically testable?
7	REVISE	Prediction + data → assessed model update	Are uncertainties, provenance, and failed tests retained?

Formal anchors

For a finite-dimensional closed subsystem, unitary evolution can be written $U(\Delta t) = \exp[-iH\Delta t/\hbar]$ and $\rho' = U\rho U^\dagger$. For an open subsystem, a channel can be represented as $\rho' = \sum_k K_k \rho K_k^\dagger$ with $\sum_k K_k K_k^\dagger = I$. For a POVM with effects E_i , $p(i) = \text{Tr}(\rho E_i)$, where E_i are positive and sum to identity. These equations define standard quantum operations; PIA must still identify the actual physical H , K_k , and E_i in each application.

Reproducible research record

- Store the model version, state basis, parameter values, initial conditions, random seeds where used, and the software implementation version.
- Retain detector calibration, uncertainty, discarded data, null results, and model provenance—not only successful outcomes.
- Separate mathematical self-tests from evidence about a physical platform. A circuit simulator can validate its algebra; it cannot establish that gravitons instantiate its registers.

MINIMAL LEGAL CYCLE

READ → MEASURE → REPRESENT → TRANSFORM → CORRELATE → PROPAGATE → READ. GEOMETRIZE* may be inserted only when the relevant physical map has been defined. The sequence is a workflow mnemonic, not a claim that all physical processes follow a fixed temporal instruction list.

13 / SYSTEMS SYNTHESIS

What this architecture contributes

PIA aims to create one vocabulary for a particle state, a relation between states, a composite system, and a possible geometric substrate. The goal is not to say “everything is a bit” and stop. The work is to specify what the representation preserves, what transformations are permitted, and what output could distinguish it from a simpler model.

Level	Primitive	Systems-information role	Evidence / status
I	Particle / field state	Differentiate and identify	Standard field-theory inventory + model representation
II	Interaction channel	Relate and transform	Dynamics and interaction amplitudes
III	Composite system	Compose and constrain	Bound states, symmetry, statistics, and gauge structure
IV	Geometry	Organize relations / candidate substrate	General Relativity tested macroscopically; deeper quantum map open
V	Measurement and inference	Measure, compare, revise	Operational outcomes and statistical inference
VI*	Programmable geometry	Candidate GEOMETRIZE operation	Speculative until a physical interface and prediction exist

How this relates to All Is Epistemic

The TOE begins from A0: ALL IS EPISTEMIC. Within this framework, “epistemic” is used as an ontological proposal about physical differentiation, relation, measure, state distinction, and constraint—not merely as a statement about human knowledge. K3—Differentiate, Relate, Measure—is the operational kernel used to guide the translation. But A0 does not logically force every downstream choice in PIA. It does not prove the graviton qdit, the opcode set, or a specific dynamical law. Those are additional claims and must earn acceptance separately.

What PIA should make easier

- Compare state encodings while preserving physical factorization and constraints.
- Specify interactions as explicit maps instead of vague verbal analogies.
- Connect quantum-state simulation, statistical readout, and model revision in one reproducible pipeline.
- Locate precisely where the proposed spacetime-computing hypothesis departs from the Standard Model and General Relativity.

THE USEFUL RESULT

The universe supplies the physical building blocks. PIA’s job is to specify the legal ways to represent and relate them—and to show where the representation helps, where it fails, and what observation could decide.

Validation, failure modes, and research roadmap

A computational ontology earns scientific value through constraints and prediction, not through metaphor. The following sequence gives the work an adversarial path forward.

Validation ladder

6. Inventory fidelity: reproduce the relevant Standard Model quantum numbers, field representations, masses/couplings with stated conventions, and known interaction channels.
7. Register fidelity: show that the proposed factorization preserves the relevant dynamics and does not double-count gauge, spin, or polarization degrees of freedom.
8. Operational fidelity: implement state preparation, gates/maps, measurements, uncertainty, and open-system channels with independently reproducible results.
9. Gravity interface: specify a 3+1D map from the Q5 register to a covariant physical description; derive constraints, stability, and conservation properties.
10. Classical recovery: recover the tested General Relativity limit, including the weak-field Newtonian behavior and two physical radiative modes in the low-energy massless sector.
11. Novel prediction: derive an observable deviation with a defined parameter range, numerical magnitude, and uncertainty, then compare with data and competing models.

Failure conditions

- The architecture merely renames standard equations and provides no explanatory, computational, or predictive gain.
- The register conflates mathematical basis states with independently physical polarizations or spatial dimensions.
- The proposed transformation violates gauge constraints, statistics, causality, unitarity, stability, or the conservation relations of its stated regime.
- The five-state gravitational register cannot be connected to known gravitational observables without arbitrary after-the-fact choices.
- The claimed effect is already predicted by the baseline theory, is not uniquely measurable, or is excluded by existing data.
- A result depends on undocumented parameters, hidden preprocessing, unreported failed runs, or a simulator bug.

Research sequence

Phase	Concrete deliverable	Exit criterion
A. Formal PIA	Versioned register schema, opcode semantics, and legality checks	No ambiguity about state, map, constraints, or output
B. Reference implementation	Deterministic tests, example programs, and reproduction notes	Independent run reproduces the outputs
C. 3+1D gravity interface	Action/Hamiltonian or effective model connecting Q5 to observables	Well-posed dynamics, controlled limit, stability analysis
D. Baseline comparison	Predictions compared with GR and standard quantum field methods	Deviations are quantified rather than narrated
E. Empirical challenge	A test proposal or retrospective data comparison	A result could falsify or support a parameterized claim

RESEARCH DISCIPLINE

A simulator passing its own tests demonstrates that the implementation behaves as specified. It does not demonstrate that the physical hypothesis is true. Mathematical consistency is necessary, but not sufficient.

Conclusion: from particle inventory to a research program

Particle Information Architecture starts with the known particle inventory and asks whether its state spaces and interaction channels can be represented in a common systems language. The particle record makes identity explicit; the interaction vocabulary names transformations; composition respects symmetry and statistics; measurement produces outcomes and uncertainty; and revision preserves the possibility of correcting the model.

The graviton extension is the most ambitious and least established layer. In the chosen 3+1D direction, the five-state qdit is an abstract computational register associated with the gravitational sector. It is not a statement that the massless graviton has five observed physical polarizations, and it introduces no extra spatial dimensions. Its scientific task is to derive how the register relates to the conventional two-helicity massless sector, how it changes effective geometry, and what quantitative prediction it makes that baseline physics does not already require.

The TOE's A0 premise, ALL IS EPISTEMIC, motivates this search for a physical grammar of distinction, relation, and measurement. It does not exempt the register design or the graviton hypothesis from proof. If PIA improves simulation, exposes a previously hidden constraint, or produces a falsifiable result, it earns a place in the research program. If it only gives familiar mathematics new names, it should remain a descriptive analogy or be discarded.

THE OPERATING MAXIM

Differentiate. Relate. Measure. Keep the representation simple, the constraints explicit, the assumptions visible, and the result vulnerable to correction. Reality wins. Always.

At a glance

Core architecture	Meaning
$P = [F, S, M, Q, R, G, \Lambda, D; \xi]$	Structured record of a particle/field sector for a specified model
Interaction $\rightarrow$ constrained state map	The physical dynamics define legal transformations
Qubit / qudit	State-space representation; not spatial dimension
GEOMETRIZE*	Conjectural map from a gravitational register to effective geometry
3+1D baseline	All spatial and temporal physics in this manuscript is formulated in three spatial dimensions and one time dimension
Reality veto	Every downstream representation and conjecture can be corrected or rejected

APPENDIX / SOURCES

References and source discipline

Physical-property claims and the Standard Model baseline should be checked against current primary data compilations. The values in the master ledger are intentionally rounded and are not intended for precision calculation. References below were consulted or are the appropriate current source families for formal checking.

- [1] Particle Data Group (2026). Review of Particle Physics, F. Takahashi et al., International Journal of Modern Physics A 41, 2630011 (2026). Main portal and particle properties: <https://pdg.lbl.gov/2026/> and https://pdg.lbl.gov/2026/listings/particle_properties.html
- [2] CERN. The Standard Model. Summary of the Standard Model particle inventory and its exclusion of gravity as a unified quantum interaction: <https://home.cern/science/physics/standard-model/>
- [3] Particle Data Group (2026). Summary Tables, with a cutoff date of 15 January 2026: https://pdg.lbl.gov/2026/tables/contents_tables.html
- [4] Particle Data Group (2026). “Quark Masses,” Review of Particle Physics, revised August 2026: <https://pdg.lbl.gov/2026/reviews/rpp2026-rev-quark-masses.pdf>
- [5] Particle Data Group. “Neutrino Masses, Mixing, and Oscillations,” Review of Particle Physics. Use the 2026 review portal for the current edition: https://pdg.lbl.gov/2026/reviews/standard_model_and_related.html
- [6] Wald, R. M. (1984). General Relativity. University of Chicago Press. See also standard treatments of the constrained degrees of freedom of massless spin-2 perturbations.
- [7] Weinberg, S. (1995). The Quantum Theory of Fields, Vol. I. Cambridge University Press. Standard background for Lorentz representations, spin, and quantum fields.
- [8] Rugai, N. (2026). Antiparticle Information Architecture: Antiparticles as Conjugate Information States in a Qubit/Qudit Framework. Companion working manuscript, October 2026.
- [9] Rugai, N. (2026). Quantum Graviton Computing: A 3+1D Framework for Five-State Gravitational Registers, Entanglement, Dynamics, and Classical Signal Extraction. Working manuscript, version 1.0, 24 October 2026.

Version notes

Item	Record
Document	Particle Information Architecture: From Fundamental Particles to Spacetime Programming
Version	2.0 — converted from the existing 12-page PDF reference into an editable Word manuscript and aligned to 3+1D TOE direction
Prepared	25 October 2026
Author	Nick Rugai, PhD
Scope boundary	WIS/TOE systems interpretation; not a replacement for the Standard Model or General Relativity
Status	Exploratory research framework; all graviton-qdit and GEOMETRIZE claims are conjectural

FINAL NOTE

The sources establish the particle-physics baseline. They do not establish that particles are computational bits, that spacetime can be programmed, or that a five-state graviton qdit exists in nature. Those are the research questions this architecture is designed to make precise.